Federal / Provincial Long Range Transport of Air Pollutants Steering Committee

Comité directeur fédéral / provincial sur le transport à distance des polluants atmosphériques

DEVELOPMENT OF A NATIONAL NITROGEN OXIDES (NO_X) AND VOLATILE ORGANIC COMPOUNDS (VOC) MANAGEMENT PLAN FOR CANADA

TECHNICAL ANNEX ON:

I ENVIRONMENTAL OBJECTIVES AND CRITERIA

II NO_X EMISSIONS AND CONTROL TECHNOLOGIES

III VOC EMISSIONS AND CONTROL TECHNOLOGIES

Province of British Columbia
Ministry of Environment and Parks

Gouvernement du Québec
Ministère de l'Environnement

Alberta
ENVIRONMENT

New Brunswick
Department of Municipal Affairs and Environment

Saskatchewan
Environment and Public Safety

Prince Edward Island
Canada
Community & Cultural Affairs

Manitoba
Environment and Workplace Safety and Health

Nova Scotia
Department of the Environment

Environment
Ontario

Province of Newfoundland
Department of the Environment

Canada

JULY 1989

INFORMATION REPORTS

DEVELOPMENT OF A NATIONAL OXIDES OF NITROGEN (NOX) AND VOLATILE ORGANIC COMPOUNDS (VOC) MANAGEMENT PLAN

PREPARED FOR:
FEDERAL PROVINCIAL ADVISORY COMMITTEE
ON AIR QUALITY

CONSERVATION AND PROTECTION
ENVIRONMENT CANADA

July 1989

Table of Contents

REPORT NO. 1

ENVIRONMENTAL OBJECTIVES AND CRITERIA

Prepared for:

Federal-Provincial Advisory Committee
on Air Quality

Conservation and Protection
Environment Canada

July 1989

Summary - Information Report on
ENVIRONMENTAL OBJECTIVES AND CRITERIA

The four categories of environmental quality requirements to consider with respect to the development of an emissions reduction plan for oxides of nitrogen and associated pollutants are:

a) Canada's National Ambient Air Quality Objectives, designed to protect human health, vegetation and materials (developed in the 1970's and now undergoing review by the Federal-Provincial Advisory Committee on Air Quality, reporting to CCME);

b) provincial and municipal air quality requirements, also designed to protect human health, vegetation and materials (developed by these jurisdictions, but largely based on the national objectives);

c) critical loads or target loads for nitrogen deposition to soil, forests and other vegetation, to protect them and associated sensitive surface and ground water (being developed internationally through the ECE Executive Body for the Convention on Long-Range Transboundary Air Pollution, and in Canada by the LRTAP Research and Monitoring Co-ordinating Committee); and

d) critical levels for air pollutants outside urban areas to protect forests, crops and materials (being developed as in c) above).

Draft recommended critical loads and critical levels have been proposed following two ECE workshops in March 1988.

The development of national objectives and provincial and municipal requirements has proceeded independent of the development of critical levels. Reconciliation of any differences in these requirements should be considered before they are finalized.

Parallel requirements are in place or under development for sulphur dioxide levels and sulphur deposition in connection with sulphur dioxide emissions reductions.

1 ENVIRONMENTAL OBJECTIVES AND CRITERIA

1.1 Introduction

Environmental quality is often judged relative to a point or points of reference established through an assessment of the results of scientific investigation of effects of pollutants on human health and the environment, and the determination of pollutant levels that will afford some degree of protection against those effects. A variety of terms, such as objectives, standards, guidelines, criteria, maximum permissible concentrations, targets, critical levels and critical loads, are used in the air pollution field to describe these points of reference, reflecting more the interest of the individuals or organizations that developed them than any fundamental difference in the purpose of putting them in place. They all represent limits which if exceeded will result in a quantitatively or qualitatively definable degree of change or damage to the environment or human health. They all represent air quality "requirements" and therefore have implications for air pollution control authorities. The use of the term standard, however, often implies the additional significance of the standard being a legally enforceable requirement.

The key environmental quality requirements to be considered with respect to the development of an emissions reduction plan for oxides of nitrogen, volatile organic compounds and associated pollutants are:

a) Canada's National Ambient Air Quality Objectives (NAAQO)
b) Provincial, territorial and municipal air quality requirements (guidelines, standards, maximum permissible concentrations, criteria, etc.)
c) Critical loads or target loads for acid deposition
d) Critical levels of air pollutants outside urban areas.

Table 1.1 is a synopsis of the status of the development of environmental quality requirements in Canada that pertain to such a control program.

1.2 Objectives

NAAQO's are developed through the Federal-Provincial Advisory Committee on Air Quality (FPACAQ) which, as of September 22, 1987, reports directly to the CCME Committee of Deputy Ministers. The FPACAQ Air Quality Objectives Subcommittee, comprised of experts in the fields of human health effects, vegetation effects and pollution measurement and control, develop the objectives for approval by FPACAQ and the CCME Deputies Committee. The objectives are then passed on to the federal Environment Department in the form of recommendations from FPACAQ/CCREM.

Consistent with the 1971 federal Clean Air Act (now subsumed by the Canadian Environmental Protection Act), NAAQO's were developed in the 1970's to reflect three ranges of air quality - desirable, acceptable and tolerable. The ranges are defined by specifying the maximum pollutant levels for each range (Figure 1.1). The current objectives will continue to be in effect under the new legislation and are undergoing review by the FPACAQ.

The following definitions are used in setting numerical values for the highest concentration levels in the desirable, acceptable and tolerable ranges.

The Maximum Desirable Level is the long-term goal for air quality and provides a basis for an anti-degradation policy for unpolluted parts of the country, and for the continuing development of control technology.

The Maximum Acceptable Level is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being.

The Maximum Tolerable Level denotes time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required without delay to protect the health of the general population.

Table 1.2 lists the current NAAQO's and the FPACAQ's recommended NAAQO's for ozone and oxides of nitrogen. Objectives for sulphur dioxide are also included as sulphur dioxide, ozone and oxides of nitrogen in combination are potentially more dangerous at lower levels than the individual pollutants acting alone.

A recent survey(1) conducted by the FPACAQ Air Quality Objectives Subcommittee revealed that all of the provinces with the exception of Nova Scotia and Prince Edward Island have provincial air quality requirements in place. Neither of the Territories has air quality requirements. Alberta, Saskatchewan, Manitoba, Quebec, New Brunswick and Newfoundland have legally adopted the NAAQO's for use in these provinces. Only Manitoba has adopted all three levels of NAAQO's, while the other provinces have single level requirements, most of which are equivalent to the maximum acceptable level NAAQO's. Nova Scotia uses NAAQO's but has not "legally" adopted them for use in the province. British Columbia and Ontario have developed their own air quality requirements for specific industry sectors in conjunction with emission objectives. There are, however, no provincial requirements in place in British Columbia for ozone and oxides of nitrogen, instead NAAQO's are used. Ontario has objectives and guidelines for a long list of pollutants, and a second set of point of impingement air quality criteria. Only Ontario has air quality requirements for substances that can be classified as volatile organic compounds.

A variety of terms are used to describe the provincial requirements (Table 1.3) but most are used without substantial definition.

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(1) Discussion Paper on the Future of the Air Quality Objectives Subcommittee - May 1988 (prepared for FPACAQ by the Subcommittee)

Four potential uses of air quality objectives were identified in a recent FPACAQ survey of federal, provincial and territorial air pollution officials(2):

1. As long-term goals to be obtained through long-term strategies,

2. In ambient air pollution control regimes to regulate normal daily emissions from industries,

3. In episode control programs to signal the need to implement short-term extraordinary control programs, and

4. In the development of air quality indices.

Objectives are also used to judge the effectiveness of technology-based controls and the need for more stringent measures.

The survey also found that the picture is quite variable across the country with respect to the actual use of the objectives. As most provinces do not as yet have long-term strategies for air quality, the objectives tend to be used informally as long-term goals. The British Columbia regional ozone control program uses the NAAQO's for ozone as goals. The sulphur dioxide control agreements in eastern Canada, however, are not based on ambient air sulphur dioxide objectives but instead specify a target sulphur deposition rate.

All provinces except Saskatchewan and Manitoba have implemented some form of ambient air pollution control regime in their jurisdictions based on taking action to prevent exceeding established provincial

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(2) Discussion Paper on Air Quality Management Strategies based on National Air Quality Objectives - May 1988 (prepared for FPACAQ by the Air Quality Subcommittee)

requirements. The regime may be incorporated into industry licenses or permits. The benefits of this approach are that specific targets can be discussed with industry and industry is more cognizant of ambient air quality levels. The limitations of this approach are the inability of industry to respond with sufficient speed to minimize air quality impacts and the difficulty in relating ambient levels to emission curtailment needs. Control technology development and implementation may be slowed because the initial emphasis is on the assimilative capacity of the environment.

Air pollutant levels in the tolerable range are the principal conditions which trigger implementation of episode control programs. British Columbia, Ontario and New Brunswick have formal episode control programs in place. The major elements of the program are public notification and voluntary or ordered cutback of offending emissions. Episodes are generally caused by both high emission levels and meteorological conditions which promote pollutant build-up.

Figures 1.2 to 1.6 indicate air quality requirements for ozone and nitrogen dioxide for some other jurisdictions relative to Canadian requirements.

1.3 Critical Loads and Critical Levels

Critical loads and critical levels are being developed through the Economic Commission for Europe (ECE) Executive Body for the Convention on Long-Range Transboundary Air Pollution, as part of the workplan for implementation of the Convention. As a result of two workshops held in March 1988, one on Critical Levels for Forests, Crops and Materials held in West Germany, and one on Critical Loads for Sulphur and Nitrogen held in Sweden, draft recommendations on loads and levels have been formulated as a basis for future deliberations on a number of specific areas of scientific uncertainty.

Critical Levels

The proposed definition of critical levels is:

"Critical levels means the concentration of pollutants in the atmosphere above which direct adverse effects on receptors, such as plants, ecosystems or materials, may occur according to present knowledge"[3].

Draft recommended critical levels for sulphur dioxide, oxides of nitrogen (NOx), ozone and ammonia plus ammonium (NHx), alone or in combination have been proposed (Table 1.2).

The process for formulating critical levels is similar in many ways to the process for formulating air quality objectives, guidelines, etc. The same scientific studies often serve both purposes. The major difference is that human health effects are not considered when setting critical levels. Both processes are limited by a) the fact that pollutants are seldom found alone in the atmosphere, and the effects of pollutants in combination are not well understood, b) low levels of pollutants can cause biochemical, physiological and cellular level changes in plants and animals, the significance of which is not well understood, and c) the influence of short-term exposure to pollutants during pollution episodes versus long-term (chronic) exposure to pollutants on the results of field experiments and observations of effects needs to be clarified. More knowledge in these areas is required to improve confidence in the setting of air quality requirements. Some reconciliation of the values recommended for critical levels with other air quality requirements is required. Differences should be explainable.

In general, the air quality requirements being proposed are expected to retard satisfactorily the processes of building and structural material degradation associated with pollution. This needs to be substantiated with respect to pollutant combinations and more information is needed on what materials are at risk.

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(3) ECE document EB.AIR/R.30, 20 June 1988

Critical Loads

The proposed definition of critical loads is:

"A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (3).

Critical loads refer to the deposition (on an area basis) of sulphur compounds in forest soils and in surface and ground water, and of nitrogen compounds in terrestrial ecosystems and surface water.

Soil mineralogy is the most important consideration in establishing critical loads, but climate, hydrology, biochemical processes and soil depth, texture, type and chemical characteristics will also influence the critical load in a particular region. The sulphur deposition rate is accounted for in the determination of critical loads for nitrogen (Figure1.7) as both sulphur and nitrogen deposition lead to acidification. Draft recommended critical loads for nitrogen for production forests (Table 1.4) and other ecosystems (Table 1.5) to prevent acidification of runoff water have been proposed. These estimates must be refined through further studies as critical load estimates must be specific for the region or area where they will be applicable. Critical loads to protect terrestrial biota in a variety of ecosystems have also been proposed (Table 1.6). Again, more work is needed to refine these estimates.

The critical load concept has been determined by the ECE workshop to be a useful working tool to support policy decisions. Critical loads are based on scientific considerations only. Development of a system for mapping critical loads and actual loadings was recommended by the workshop.

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(3) ECE Document E.B. Air/R.30, 20 June 1988

TABLE 1.1
Status of environmental quality requirements in Canada that pertain to the development of an emissions reduction plan for oxides of nitrogen and volatile organic compounds

REQUIREMENTS	HOW DEVELOPED	DEVELOPED TO PROTECT	STATUS	COMMENT
1. National Ambient Air Quality Objectives (NAAQO's)	Through the Federal-Provincial Advisory Committee on Air Quality (FPACAQ) of CCREM	Human health, vegetation and materials (from the direct effects of the pollutants acting alone)	Objectives in place for five* pollutants, ongoing review by FPACAQ**	Ozone formation and acid rain were not factored into the development of the objectives for nitrogen dioxide. The role of ozone in acid rain was not factored into the objectives for ozone.
2. Provincial and territorial air quality requirements	Either developed by each jurisdiction or NAAQO's are adopted	Human health, vegetation and materials	See section 2	
3. Critical loads for pollutant deposition	In Canada, through the LRTAP Research and Monitoring Co-ordinating Committee (linked to CCREM), and internationally, through the ECE	Sensitive surface and ground water, soils, forests and vegetation	Draft recommended critical loads for sulphur and nitrogen in place	ECE recommendations only, for deposition to soil, forests and managed and unmanaged vegetation. Human health effects not considered.
4. Critical levels for airborne pollutants outside urban areas	"	Forests, Crops, Materials	Draft recommended levels for four*** pollutants	Levels are for the pollutants alone or in combination. Human health effects not considered.

* NAAQO's have been developed for sulphur dioxide, carbon monoxide, particulate matter, ozone and nitrogen dioxide, but only those for ozone, nitrogen dioxide and sulphur dioxide are relevant to a control program for oxides of nitrogen and volatile organic compounds.
** covers the five above plus hydrogen sulphide and hydrogen fluoride.
*** sulphur dioxide, oxides of nitrogen, ozone and ammonia plus ammonium (NHx).

TABLE 1.2
CURRENT AND RECOMMENDED (a) NATIONAL AMBIENT AIR QUALITY OBJECTIVES AND CRITICAL LEVELS FOR OXIDANTS (OZONE), NITROGEN DIOXIDE, AMMONIA AND SULPHUR DIOXIDE

	AIR QUALITY OBJECTIVES			CRITICAL LEVELS (e)		
Contaminant	Current Air Quality Objectives	Recommended Air Quality Objectives	Exposure Period	Exposure (duration in hours)	Concentrations ug/m3	ppm
Oxidants (Ozone)						
maximum desirable levels	30 ug/m3 (0.015 ppm)	b	24-hour	0.5	300	0.150
	100 ug/m3 (0.05)	100 ug/m3 (0.05 ppm)	1-hour	1.0	150	0.075
maximum acceptable levels	50 ug/m3 (0.025 ppm)	b	24-hour	2.0	110	0.055
	160 ug/m3 (0.08 ppm)	160 ug/m3 (0.08 ppm)	1-hour	4.0	80	0.040
	30 ug/m3 (0.015 ppm) (c)	b	annual	8.0	60	0.030
		64 ug/m3 (0.032 ppm)(d)	seasonal mean			
maximum tolerable levels	300 ug/m3 (0.15 ppm)	400 ug/m3 (0.2 ppm)	1-hour	Vegetation/Growing Period (Average of 7-hour mean/day, 9 a.m. to 4 p.m.)	50	0.025
Nitrogen Dioxide						
maximum desirable levels	60 ug/m3 (0.03 ppm)	60 ug/m3 (0.03 ppm)	annual			
maximum acceptable levels	100 ug/m3 (0.05 ppm)	100 ug/m3 (0.05 ppm)	annual	annual	30 ug/m3[f]	
	200 ug/m3 (0.11 ppm)	b	24-hour			
	400 ug/m3 (0.21 ppm)	400 ug/m3 (0.21 ppm)	1-hour	4-hour	95 ug/m3[f]	
maximum tolerable levels	300 ug/m3 (0.16 ppm)	b	24-hour			
	1000 ug/m3 (0.53 ppm)	1000 ug/m3 (0.53 ppm)	1-hour			
Ammonia	No air quality objectives			monthly	100 ug/m3	(0.14 ppm)
				24-hour	600 ug/m3	(0.86 ppm)
				1-hour	10,000 ug/m3	(14.3 ppm)
Sulphur Dioxide						
maximum desirable levels	30 ug/m3 (0.01 ppm)	30 ug/m3 (0.01 ppm)	annual			
	150 ug/m3 (0.06 ppm)	150 ug/m3 (0.06 ppm)	24-hour			
	450 ug/m3 (0.17 ppm)	450 ug/m3 (0.17 ppm)	1-hour			
maximum acceptable levels	60 ug/m3 (0.02 ppm)	60 ug/m3 (0.02 ppm)	annual	annual	30 ug/m3[g]	
	300 ug/m3 (0.11 ppm)	300 ug/m3 (0.11 ppm)	24-hour			
	900 ug/m3 (0.34 ppm)	900 ug/m3 (0.34 ppm)	1-hour	4-hour	95 ug/m3[g]	
maximum tolerable levels	800 ug/m3 (0.3 ppm)	800 ug/m3 (0.3 ppm)	24 hour			

(a) Recommendations have been made by the CCREM Federal-Provincial Advisory Committee on Air Quality to the federal Department of the Environment.
(b) The recommendation is to rescind the current objective.
(c) There currently is no seasonal objective for ozone.
(d) A maximum acceptable level seasonal mean is recommended to prevent significant injury to the most susceptible vegetation during the peak growing months. The recommended level is near the levels occurring at the ground in rural areas due to natural sources of ozone.
(e) ECE draft critical levels.
(f) Nitrogen dioxide in combination with sulphur dioxide and ozone, as oxides of nitrogen are never found in isolation in the atmosphere.
(g) For sulphur dioxide acting alone.

TABLE 1.3

CANADIAN* AIR QUALITY REQUIREMENTS

	NITROGEN DIOXIDE (micrograms per cubic metre of ambient air)			OZONE (micrograms per cubic metre of air)		
	ANNUAL MEAN	24-HOUR AVERAGE	1-HOUR AVERAGE	ANNUAL MEAN	24-HOUR AVERAGE	1-HOUR AVERAGE
NATIONAL						
maximum desirable level	60				30	100
maximimum acceptable level	100	200	400	30	50	160
maximum tolerable level		300	1000			300
BRITISH COLUMBIA						
Level A						
Level B						
Level C						
ALBERTA						
maximum permissible concentrations	60	200	400		50	160
SASKATCHEWAN						
present standard	100	200	400		30	100
proposed standard					50	160
MANITOBA						
maximum desirable level	60				30	100
maximum acceptable level	100	200	400	30	50	160
maximum tolerable level			1000			400
ONTARIO						
ambient air criteria		200	400			165
QUEBEC						
ambient air standard	103	207	414			157
Montreal Urban Community standard **	100	200	400			
NEW BRUNSWICK						
maximum permissible ground level concentration	100	200	400			
NOVA SCOTIA ***						
PRINCE EDWARD ISLAND						
NEWFOUNDLAND						
acceptable criteria		200	400	30	50	160

* Prince Edward Island, the Northwest Territories and the Yukon Territory do not have air quality requirements specific to their jurisdictions.

** The Montreal Urban Community also has an 8-hour standard of 253 ug/m^3.

*** Nova Scotia uses the National Ambient Air Quality Objectives but has not legally adopted them.

TABLE 1.4
CRITICAL N LOADS FOR PRODUCTION FORESTS (kg N $ha^{-1}yr^{-1}$)[a/]
(ON WELL-DRAINED SITES ASSUMING WHOLE TREE HARVEST)

	N-accumulation in growth	Acceptable N-accumulation in soil	Leaching[b/]	Critical N input[b/]
Low productivity, net N immobilization	1 - 6	1 - 3	1 - 2	3 - 11
Low productivity, net N mineralization	1 - 6	-	-	0[c/]
High productivity, net N immobilization	5 - 15	1 - 3	1 - 2	7 - 20
High productivity, net N mineralization	5 - 15	-	-	0[c/]

a/ Values can be coverted into moles $m^{-2}yr^{-1}$ by dividing by 140.
b/ Critical N input may approach weathering rate if sulphur load is low.
c/ Any N input to declining systems will delay recovery.

TABLE 1.5
CRITICAL N LOADS FOR ECOSYSTEMS VARYING IN PRODUCTIVITY (kg N $ha^{-1}yr^{-1}$)

Ecosystem	Critical Load
Deciduous forests[b/]	5 - 20[a/]
Coniferous Forest[b/]	3 - 15[a/]
Dwarf shrub vegetation	3 - 5[c/]
Grassland (e.g. mesobrometum)	3 - 10[c/]
Raised bog	3 - 5[c/]

a/ In mature forests the critical load may approach 0.
b/ Declining systems should approach 0.
c/ Without major removal of N by management.

TABLE 1.6
SUMMARY OF BIOLOGICAL CONSEQUENCES AND CRITICAL LOADS

System	Criteria	Estimated critical load kg N $ha^{-1}yr^{-1}$
Littorella communities	Shallow soft water communities sensitive to ammonium when nitrate is low, critical load as ammonium	3 - 7
Raised bogs	Sphagnum very sensitive to nitrate (but less sensitive to ammonium). Response in a very short time due to toxicity, 5 - 10 kg during less than 1 yr.	-
	Possible changes in flora, e.g. increased growth of bushes and trees but other nutrients, e.g. limit growth rather soon.	5 - 10
Heathlands	Reduced frost resistance in Calluna	5 - 20
	Changes in species composition depends on weathering capacity. Low buffering soils.	7 - 10
	Heath to grassland conversion (complete change)	20
	With intensive management (grazing + cyclical burning + topsoil removal), Calluna and Erica can be maintained.	40
Coniferous forests	Nutrient imbalances due to high nitrogen input depends on magnesium and calcium concentration and nitrification rate. Most sensitive systems.	10 - 12
	Changes in herbaceous flora towards nitrophilic species but critical load depends on uptake by trees and saturation.	20
	Pine stands with management; positive growth response during 15 years with an annual fertilizer application as ammonium nitrate up to 30 kg, but changes in ground flora	
Deciduous forests	Changes in herbaceous flora towards nitrophilic species	15

FIGURE 1.1
CANADA'S THREE-TIERED SYSTEM OF AIR QUALITY OBJECTIVES

High Pollutant Levels

maximum tolerable level

Tolerable Range of Air Quality

maximum acceptable level

Acceptable Range of Air Quality

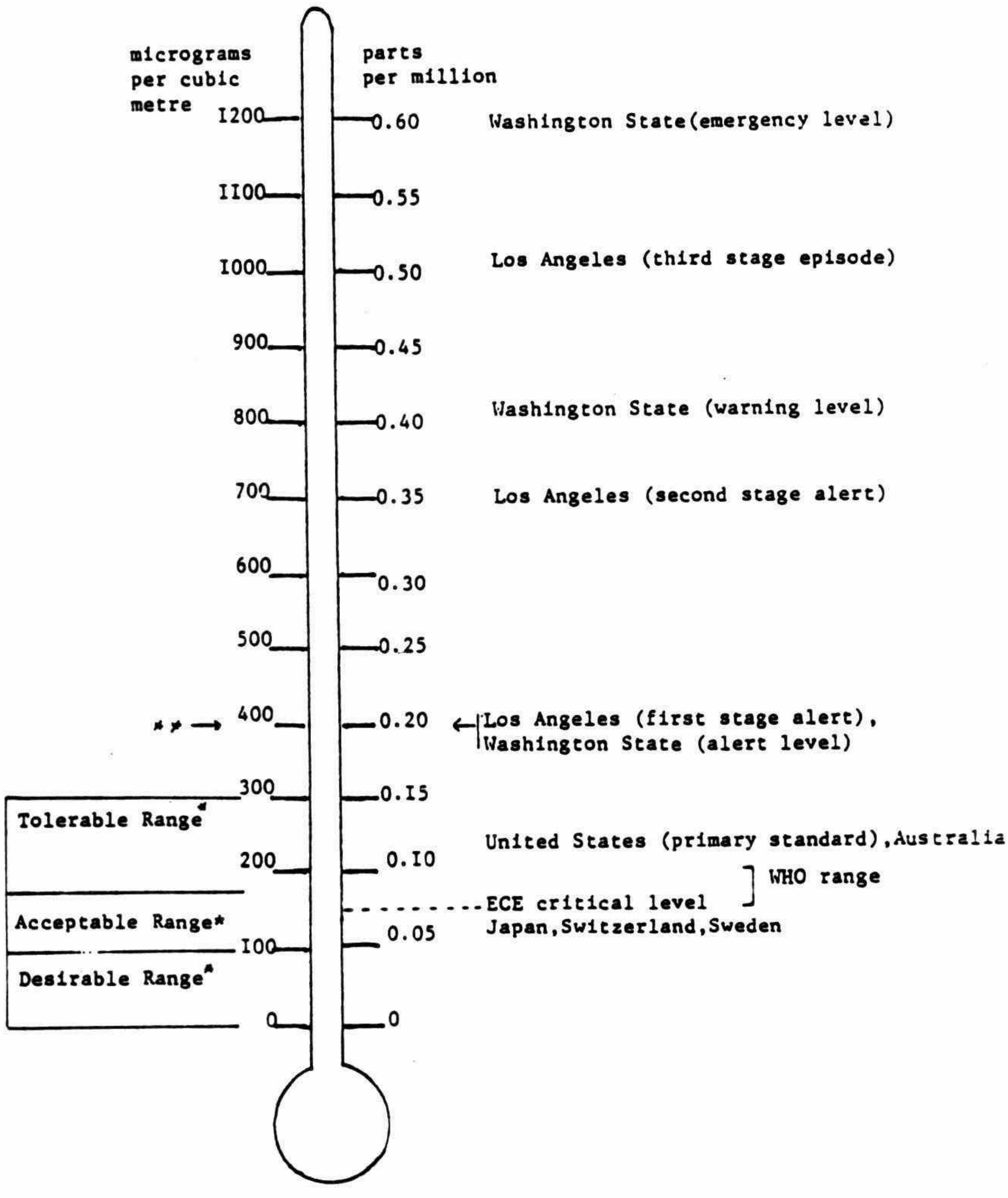
maximum desirable level

Desirable Range of Air Quality

Low Pollutant Levels

FIGURE 1.2

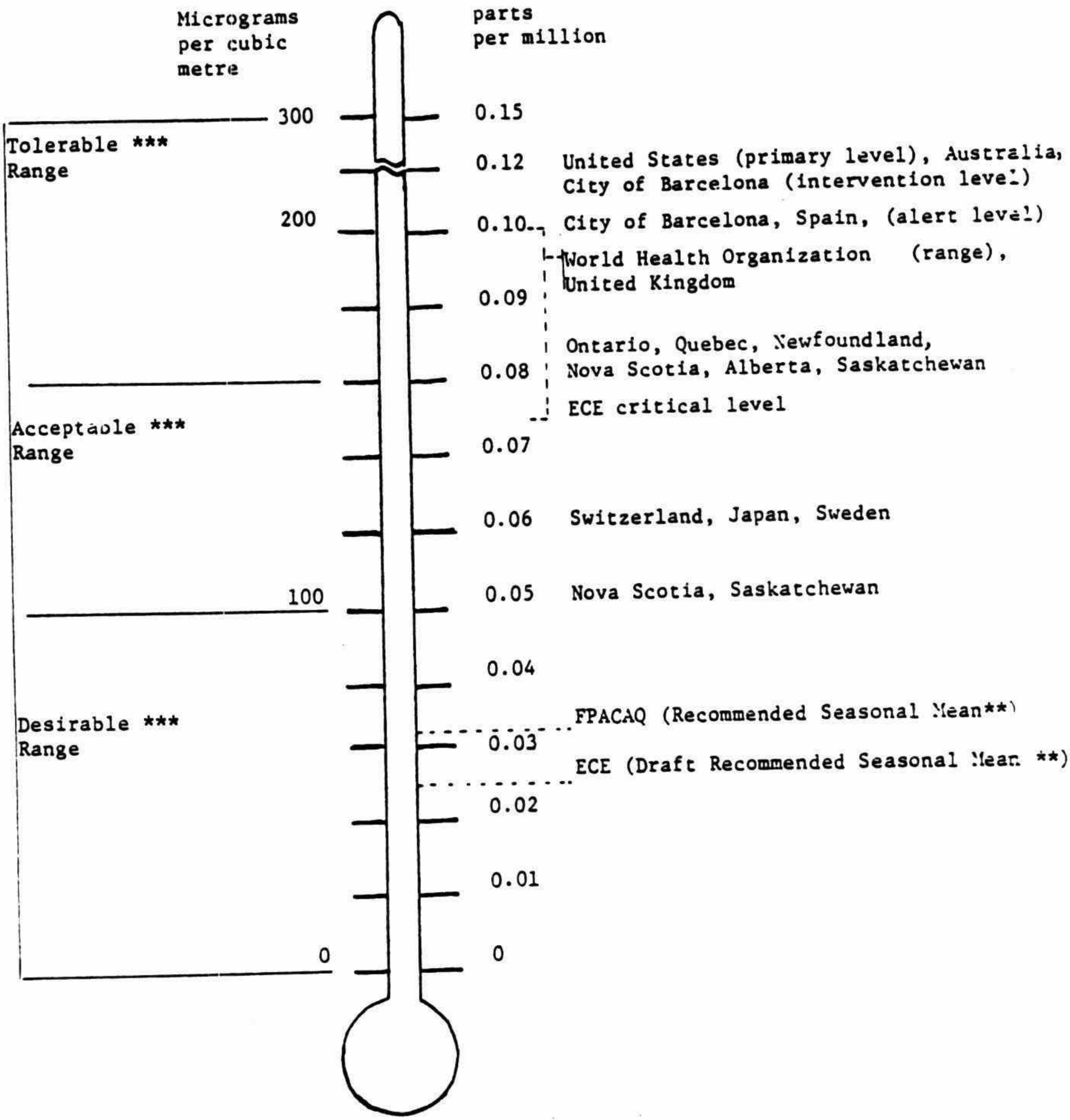
Ozone One Hour Air Quality Requirements



* Canada's National Ambient Air Quality Objectives

** FPACAQ Recommended Maximum Tolerable Level

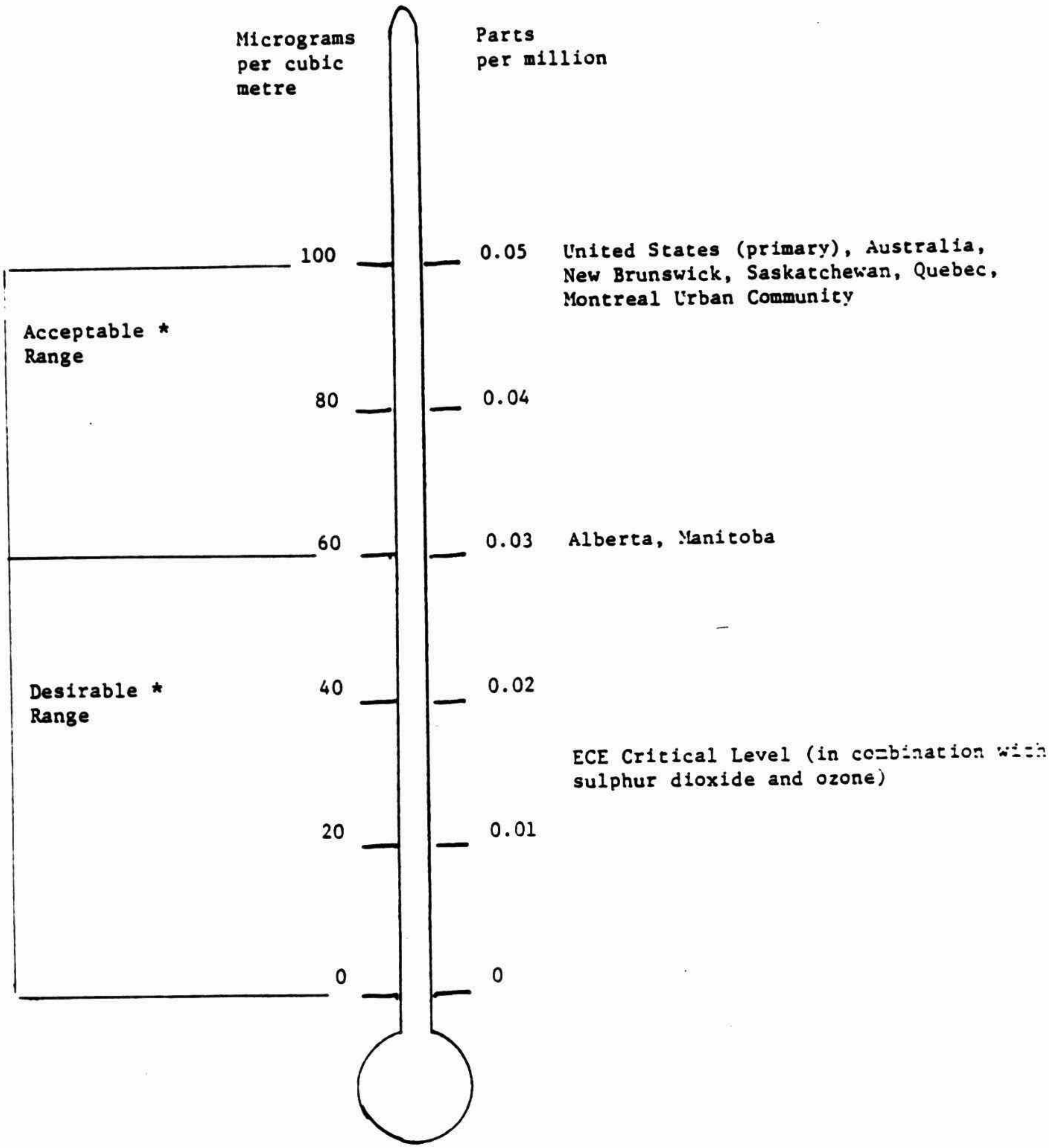
FIGURE 1.3
Ozone One-Hour Air Quality Requirements *



* An expansion of the scale used in Figure 2
** To protect vegetation
*** Canada's National Ambient Air Quality Objectives

FIGURE 1.4

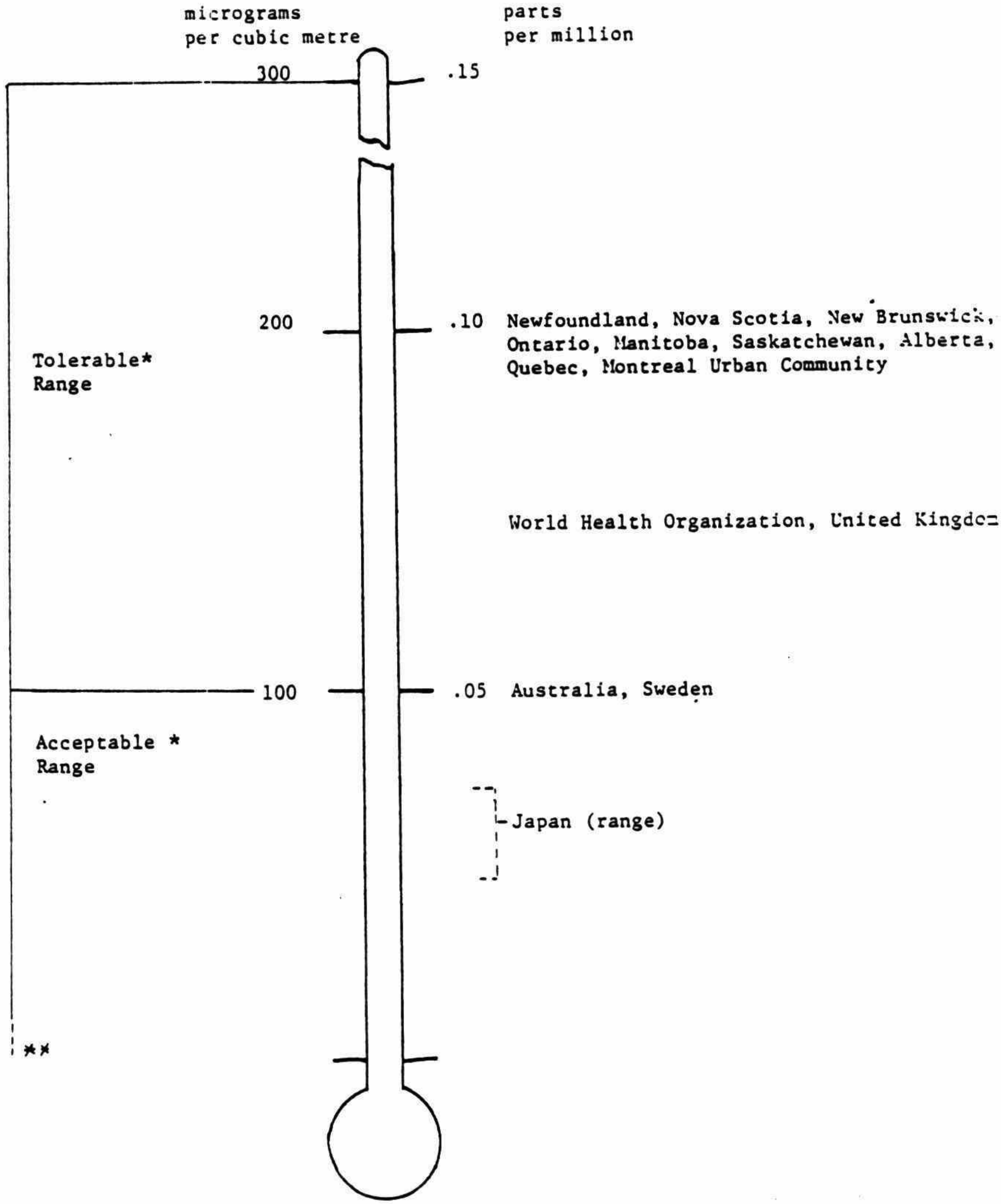
Nitrogen Dioxide Annual Air Quality Requirements



* Canada's National Ambient Air Quality Objectives

FIGURE 1.5

Nitrogen Dioxide 24-Hour Air Quality Requirements

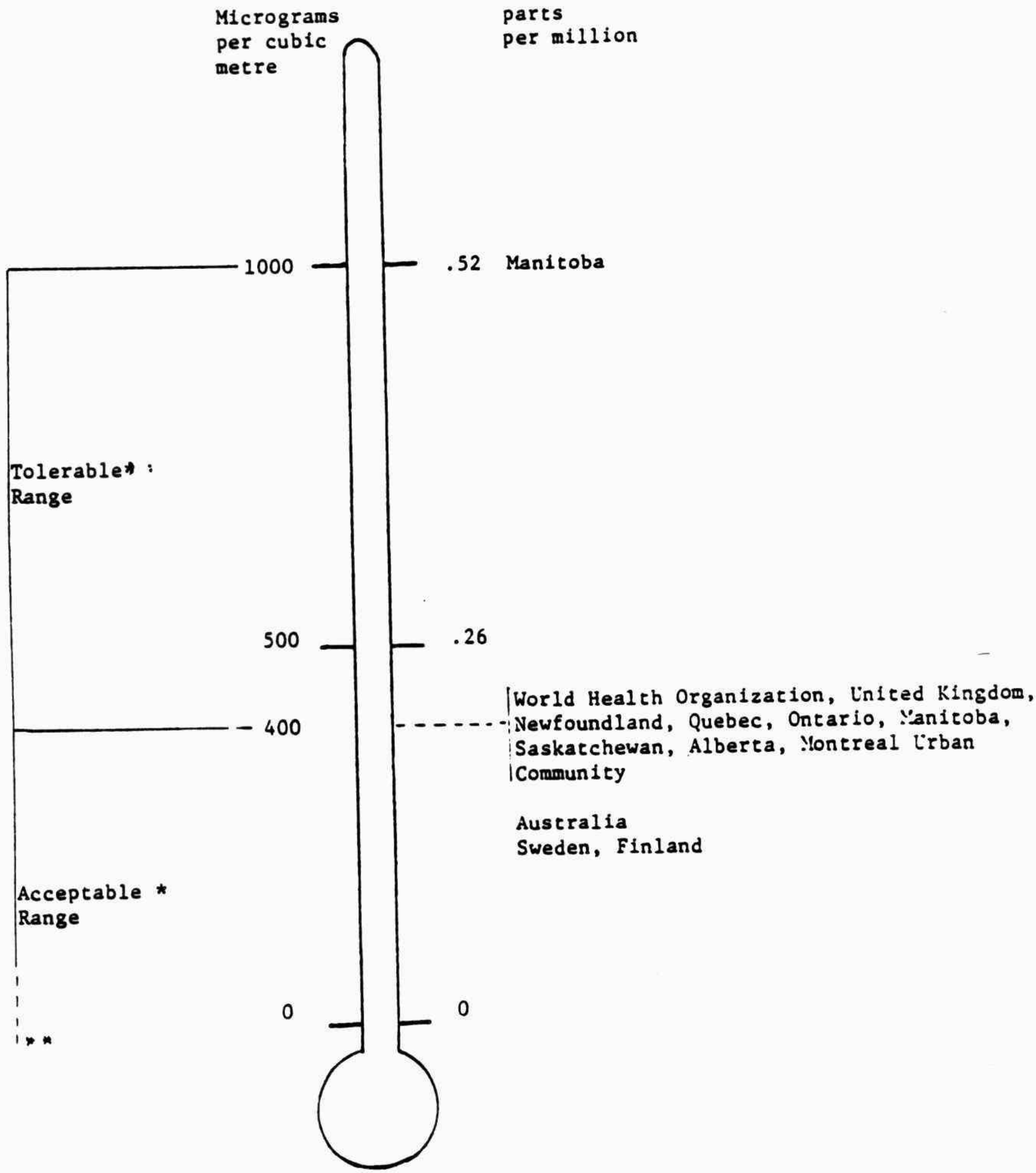


* Canada's National Ambient Air Quality Objectives

** There is no 24-hour maximum desirable level

FIGURE 1.6

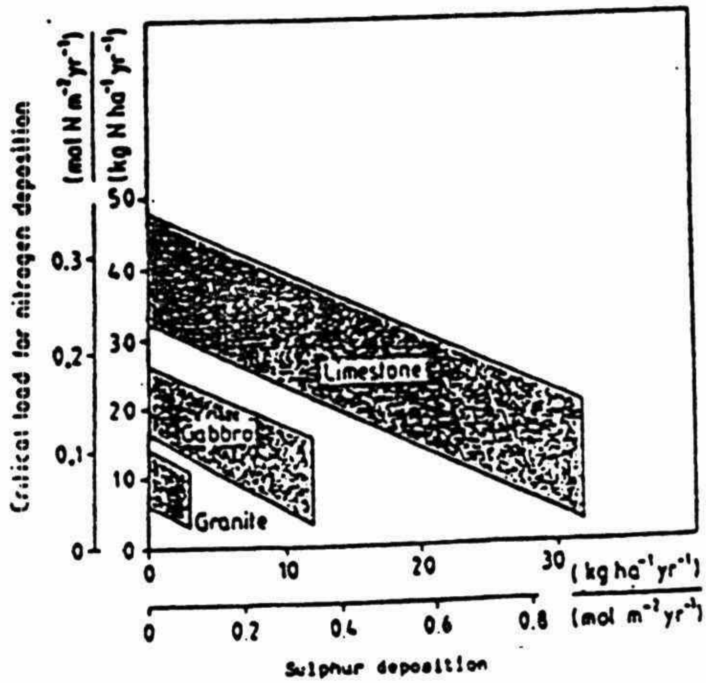
Nitrogen Dioxide One-Hour Air Quality Requirements



* Canada's National Ambient Air Quality Objectives
** There is no one-hour maximum desirable level

FIGURE 1.7

Critical loads for nitrogen and sulphur for conditions of base cation removal at the rate of weathering. (The range represents biomass removal and net accumulation.)



REPORT NO. 2.1

NOx EMISSION INVENTORY - 1985

Prepared for:

Federal-Provincial Advisory Committee
on Air Quality

Conservation and Protection
Environment Canada

July 1989

2.1 NO_x EMISSION INVENTORY - 1985

The objective of this section of the NO_x information report is to provide an estimate of the national and provincial emissions of nitrogen oxides (NO_x). The estimates presented in the following tables and figure essentially represent calculated emission estimates since few results of measurement programs were available. They are useful in identifying the sources of NO_x, their distribution and their relative magnitudes.

The inventory was compiled using provincially and federally developed emission data. A short description of the methodology used follows.

2.1.1 Methodology

Industrial Processes: Table 2.1.2

Generally, the emission data for industrial processes, such as:

° petroleum refineries;
° pulp and paper plants;
° natural gas processing;
° petrochemical plants;
° (and) other industrial sources.

were supplied by the provinces for the sources in their jurisdiction. These data were collected either as part of the provincial contribution to the national inventory of air pollutants (i.e., SO_2, NO_x, HCs, CO and particulate matter) or, as required, to support provincial air pollution programs. The emission estimates were developed from stack testing data or by using standard inventory techniques combining plant production data and emission factors. When the data were not available from the provinces, the emissions were estimated by using the latest published emission factors combined with information on the industrial processes used and reported industry (plant) production and/or consumption figures.

Fuel Combustion - Stationary Sources: Table 2.1.3

This category includes the emissions due to the combustion of fossil fuels in thermal power plants, in industrial sectors and in commercial and residential sectors. The emissions from power plants were either provided by the provinces or obtained from provincial power commissions. The emissions from industrial, commercial and residential fuel combustion were estimated by Environment Canada from fuel consumption statistics compiled by Statistics Canada and from published emission factors available by fuel type.

Although an attempt was made to segregate the emissions originating from industrial processes per se from those due to fuel combustion (normally reported under this category of the inventory), this was not always possible. In some instances, the emissions reported under the industrial processes category for the provinces of Alberta and Ontario also include emissions from fuel combustion. The possibility of double counting of emissions exists and consequently, these data will have to be reviewed further.

Transportation: Table 2.1.4

The transportation category includes the emissions from the combustion of fuel in all forms of mobile equipment. This includes emissions from motor vehicles, from other forms of mass transport such as rail and marine and from the industrial or commercial use of mobile equipment such as construction equipment and agricultural machinery.

The emissions from gasoline and diesel-powered and motor vehicles were estimated by Environment Canada and were based on vehicle population figures, vehicle-miles traveled and emission factors. The emission factors were based on the Canadian version of MOBILE 3, a transportation model developed by the U.S. EPA and are national averages representative of the vehicle fleet, by vehicle type. The figures used for vehicle-miles traveled are also national averages and were derived from studies done by Transport Canada. Provincial

vehicle population figures were taken from statistics published by Statistics Canada.

Since these estimates are based on data and model parameters which reflect, for the most part, national averages, provincial emission estimates can be refined by incorporating into MOBILE 3 parameters more representative of local conditions.

The emissions from the other mobile sources considered under the Transportation Category were generally derived using fuel consumption statistics, as reported by Statistics Canada, and emission factors. It should be noted that the emission factors for a number of these sources have undergone revisions and are different from those reported previously in the literature and which were used in other inventory estimates. This is particularly the case for emission factors applicable to:

- rail transport;
- industrial diesel equipment;
- gasoline and diesel farm machinery.

Incineration and Miscellaneous Sources: Table 2.1.5

The emissions from these two categories were also calculated by Environment Canada. Emissions from the incineration of solid waste were based on the amount of municipal refuse burned and wood waste and on average emission factors. The emissions from slash burning were based on the number of acres of slash burned and emission factors reported in the literature.

2.1.2 Results

Nationally, the emissions of nitrogen oxides amount more than 1.9 million tonnes. The emissions are due primarily to the combustion of fuel in stationary sources and in mobile sources, the transportation category contributing about 1.3 million tonnes or 64% of the national

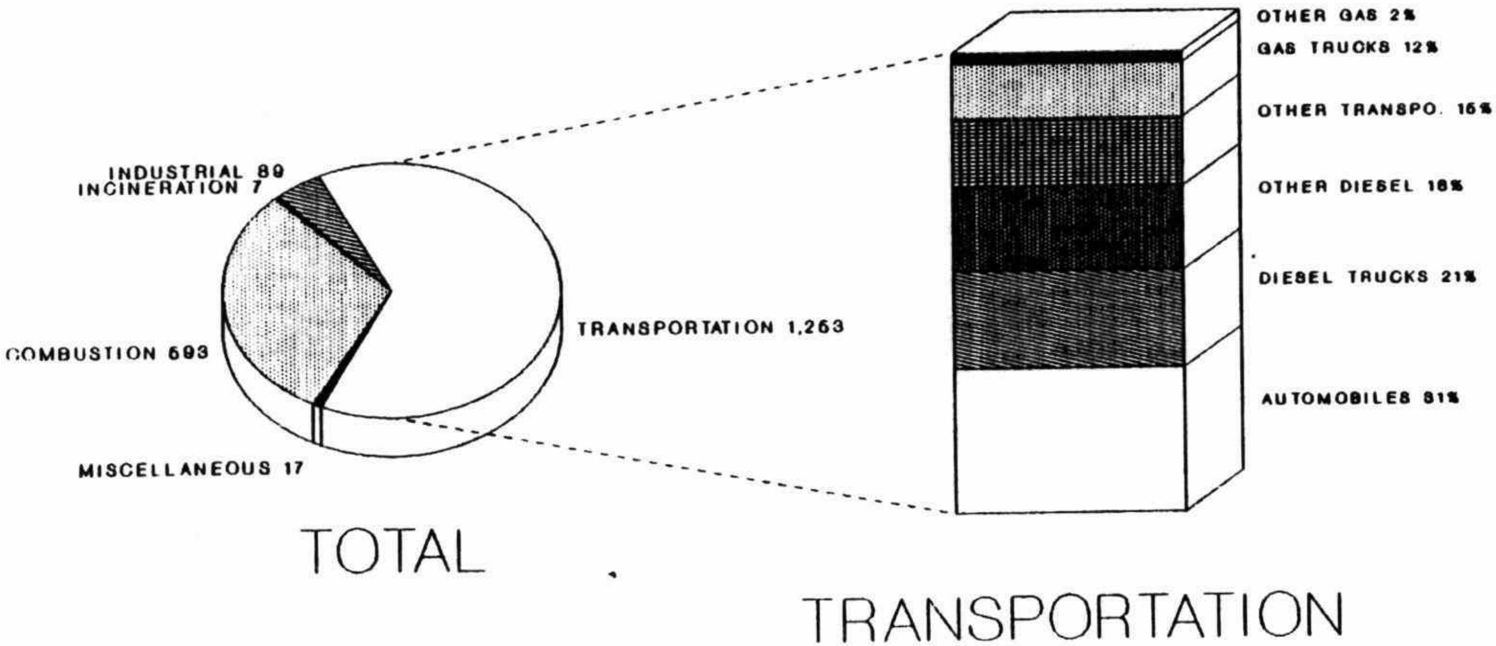
total while fuel combustion in stationary sources contributed about 0.6 million tonnes or 30% of the national total.

A similar trend is evident provincially, with the exception of the province of Alberta, where fuel combustion emissions from stationary sources predominate (50%), with transportation contributing a little less (44%). This is due in large measure to fuel combustion emissions from the natural gas processing sector which contributes about 131 kilotonnes to the Alberta inventory.

The results of the NO_x inventory nationally and provincially by category and sector are presented in Table 2.1.1 through 2.1.5 and in Figure 2.1.1.

FIGURE 2.1.1

NITROGEN OXIDES EMISSIONS 1985
NATIONAL



(KILOTONNES)

TABLE 2.1.1
SUMMARY OF PROVINCIAL NITROGEN OXIDES EMISSIONS - 1985
BY MAJOR CATEGORY

Emissions (tonnes)

CATEGORY	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
Industrial	1,320	0	1,585	2,647	6,860	38,154	572	857	26,243	10,693	0	0	88,931
Fuel Combustion	8,953	618	27,618	13,489	34,246	168,155	7,622	61,316	222,404	45,238	3,732	0	593,391
Transportation	24,502	5,312	47,914	29,053	192,759	376,344	76,147	95,617	197,060	195,783	10,284	2,126	1,252,901
Incineration	68	19	136	170	1,851	2,160	146	156	471	2,263	10	0	7,450
Miscellaneous	295	48	404	928	4,160	317	202	355	1,055	9,033	22	0	16,819
Total	35,138	5,997	77,657	46,287	239,876	585,130	84,689	158,301	447,233	263,010	14,048	2,126	1,959,492

TABLE 2.1.2
PROVINCIAL EMISSIONS OF NITROGEN OXIDES
INDUSTRIAL PROCESSES CATEGORY - 1985

Emissions (tonnes)

SECTOR	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
Crude Oil	-	-	-	-	-	-	-	-	-	-	-	-	0
Refineries	0	-	1,177	51	360	9,043	0	197	2,664	1,887	-	-	15,379
Gas Plants	-	-	-	-	-	0	-	0	0	0	-	-	0
Coal Prod.	-	-	-	-	-	-	-	-	-	-	-	-	0
Petrochemicals	-	-	-	-	-	-	-	-	-	-	-	-	0
Plastics	-	-	-	-	-	-	-	-	-	-	-	-	0
Kraft Pulping	-	-	242	2,596	3,768	3,287	229	606	750	6,710	-	-	18,188
Tar Sands	-	-	-	-	-	-	-	15,975	-	-	-	-	15,975
Other	1,320	-	166	-	2,732	25,824	343	54	6,854	2,096	-	-	39,389
TOTAL	1,320	0	1.585	2,647	6,860	38,154	572	857	26,243	10,693	0	0	88,931

TABLE 2.1.3
PROVINCIAL EMISSIONS OF NITROGEN OXIDES
STATIONARY FUEL COMBUSTION CATEGORY - 1985

Emissions (tonnes)

SECTOR	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
INDUSTRIAL													
Refineries	0	-	1,144	1,254	4,432	8,687	0	591	411	277	-	-	16,796
Gas Plants	-	-	-	-	-	446	-	16,919	131,480	9,878	-	-	158,723
Other Industrial	2,354	36	1,786	2,624	16,914	36,437	2,168	4,218	10,936	25,145	72	-	102,690
SUBTOTAL	2,354	36	2,930	3,878	21,346	45,570	2,168	21,728	142,827	35,300	72	-	278,209
Commercial	413	112	1,155	631	3,941	9,660	1,290	1,139	4,534	2,711	312	-	25,898
Residential	467	210	1,591	815	6,519	13,887	1,375	2,208	6,920	3,392	109	-	37,493
Fuelwood	374	193	199	227	966	1,465	84	101	67	166	57	-	3,899
POWER PLANTS													
Utilities	3,808	67	21,676	7,929	0	94,600	1,781	35,733	67,810	1,657	-	-	235,061
Other	1,537	0	67	9	1,474	2,973	924	407	246	2,012	3,182	-	12,831
SUBTOTAL	5,345	67	21,743	7,938	1,474	97,573	2,705	36,140	68,056	3,669	3,182	-	247,892
TOTAL	8,953	618	27,618	13,489	34,246	168,155	7,622	61,316	222,404	45,238	3,732	-	593,391

NOTE : Emission estimates for N.W.T. include Yukon.
Statistics for Yukon were not reported separately.

TABLE 2.1.4
PROVINCIAL EMISSIONS OF NITROGEN OXIDES
TRANSPORTATION CATEGORY - 1985

Emissions (tonnes)

SECTOR	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
GASOLINE													
Automobiles	5,904	1,912	12,836	9,749	87,056	145,839	17,974	13,575	45,187	51,475	314	256	392,077
L-D Trucks	2,849	743	5,617	4,511	11,866	36,751	8,213	11,716	15,246	24,742	512	485	123,251
H-D Trucks	615	172	1,041	836	2,910	7,469	1,522	2,464	3,212	4,585	99	94	25,019
Motorcycles	22	5	41	26	229	309	40	18	101	173	2	2	968
SUBTOTAL	9,390	2,832	19,535	15,122	102,061	190,368	27,749	27,773	63,746	80,975	927	837	541,315
DIESEL													
L-D Trucks	95	25	187	150	394	1,477	273	389	506	822	17	16	4,351
H-D Trucks	5,252	1,398	12,084	8,315	27,162	88,827	15,325	22,851	31,700	45,609	1,050	1,104	260,677
Other *	6,257	695	9,675	4,470	29,093	43,676	10,307	24,890	50,454	44,022	6,765	-	230,304
SUBTOTAL	11,604	2,118	21,946	12,935	56,649	133,980	25,905	48,130	82,660	90,453	7,832	1,120	495,332
Total Road	20,994	4,950	41,481	28,057	158,710	324,348	53,654	75,903	146,406	171,428	8,759	1,957	1,036,647
Railroads *	907	108	4,324	266	17,904	32,144	18,215	10,220	35,802	17,809	140	-	137,839
Marine *	813	40	293	51	8,628	5,678	13	9	16	1,193	13	-	16,747
Aircraft	1,316	114	1,389	191	6,041	10,110	1,833	3,342	4,753	3,133	1,148	129	33,499
Off-road Gas	472	100	427	488	1,476	4,064	2,432	6,143	10,083	2,220	224	40	28,169
TOTAL	24,502	5,312	47,914	29,053	192,759	376,344	76,147	95,617	197,060	195,783	10,284	2,126	1,252,901

* Emission estimates for Yukon are included under N.W.T.
Statistics for Yukon were not reported separately.

TABLE 2.1.5
PROVINCIAL EMISSIONS OF NITROGEN OXIDES
INCINERATION AND MISCELLANEOUS CATEGORIES - 1985

Emissions (tonnes)

SECTOR		NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
INCINERATION :														
Wood Waste		5	2	28	65	541	279	8	32	147	1,886	-	-	2,993
Other		63	17	108	105	1,310	1,881	138	124	324	377	10	-	4,457
	TOTAL	68	19	136	170	1,851	2,160	146	156	471	2,263	10	-	7,450
MISCELLANEOUS :														
Fuel Marketing		-	-	-	-	-	-	-	-	-	-	-	-	0
Structural Fires		-	-	-	-	-	-	-	-	-	-	-	-	0
Slash Burning		295	48	404	928	4,160	317	202	355	1,055	9,033	22	-	16,819
	TOTAL	295	48	404	928	4,160	317	202	355	1,055	9,033	22	-	16,819

NOTE : Estimates for Yukon are included under N.W.T.
Statistics for Yukon were not reported separately.

REPORT NO. 2.2

NOx EMISSION PROJECTIONS 1985-2005

Prepared for:

Federal-Provincial Advisory Committee on Air Quality

Conservation and Protection
Environment Canada

July 1989

2.2 NO_x EMISSIONS PROJECTIONS 1985 - 2005

Revised forecasts have been generated for Canada and the provinces/territories using 1985 emission estimates as the base year extending to the year 2005. Modifications have been taken into account:

- new energy demand forecasts prepared by the National Energy Board;
- new electric power emission forecasts as generated by Environment Canada;
- new compressor engine regulations by Alberta Environment;
- new industry growth data generated by Informetrica.

The accompanying tables and figures by province/territory and for Canada provide a clear picture of NOx emissions for all sectors. Sources contributing significantly to total emissions have been segregated from the category totals.

The major assumptions in developing the forecasts are:

- status quo emission controls - Current vehicle standards and low NOx burners on new power plants are included.
- National Energy Board (NEB) estimates have been used for car and truck stock growth rates.
- NEB estimates of energy demand were used for fuel consumption for all energy related sectors by fuel type and by province/territory.
- Informetrica economic and population growth estimates were used for other sources (by sector and by province/territory).
- Electricity growth rates and fuel mixes were used to forecast emissions for power plants.

A summary of the generic methodology used in developing the forecasts including data sources for the base year inventory is included in Appendix A.

Based on these changes, the current national projections show a 354 kilotonne or a 18% increase between 1985 and 2005. Although the magnitude of the increase is similar to the original data set, there exist significant differences in three sectors:

- heavy-duty diesel truck emissions will increase by 152 kilotonnes or 58% over the forecast period. This compares to a 5% decrease in the original forecast data. Growth in truck stock over the 20-year period, based on National Energy Board forecasts, attributes to this change;

- emissions from the power generation sector will increase by 104 kilotonnes or 42% between 1985 and 2005. This compares to an increase of 94% in the original data. This change is due to the new emission forecasts generated by Environment Canada;

- industrial fuel combustion emissions will only increase by 13 kilotonnes or by 5%. Now taking into consideration an Alberta regulation that limits NO_x emissions in new compressor engines, these data compare with an increase of 40% in the original forecasts.

Generally, all categories of NO_x emissions show increases in the time period shown. Transportation emissions increase 14%, emissions from industrial processes by 57%, incineration and miscellaneous sources by 42% and stationary fuel combustion (not including power generation) by only 3%.

TABLE 2.2.1
NO_x PROJECTIONS - CANADA
(Kilotonnes)

PROVINCE: Canada

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	390.8	331.8	262.2	245.9	262.3
Light-Duty Trucks					
Gas	122.6	137.5	139.5	127.7	120.1
Diesel	4.4	4.4	4.9	6.4	8.0
Heavy-Duty Trucks					
Gas	25.0	29.3	34.0	38.7	43.9
Diesel	260.8	266.3	280.7	333.2	413.1
Off-Road Diesel					
Construction	31.3	32.0	36.0	41.7	49.4
Agriculture	53.5	64.8	70.2	74.8	81.0
Railroads	139.9	144.0	154.6	164.0	175.7
Other	145.6	149.7	168.0	180.1	187.0
Other	79.4	82.8	84.1	86.2	90.7
Fuel Combustion					
Residential	41.5	37.3	37.2	37.2	36.9
Commercial	25.8	25.9	27.3	27.8	28.4
Industrial					
Natural Gas	158.8	155.3	152.5	136.0	112.5
Other	119.4	131.8	150.5	163.7	178.9
Power Generation	247.9	287.7	319.2	363.9	351.7
Industrial Processes	89.0	89.9	104.0	119.8	139.7
Incineration/Miscellaneous	24.3	27.2	29.2	31.9	34.6
T O T A L	1960.0	1997.7	2054.1	2179.0	2313.9

TABLE 2.2.2
NO_X PROJECTIONS - NEWFOUNDLAND
(Kilotonnes)

PROVINCE: Newfoundland

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	5.9	5.0	4.0	3.7	4.0
Light-Duty Trucks					
Gas	2.8	3.2	3.3	3.0	2.8
Diesel	0.1	0.1	0.1	0.2	0.2
Heavy-Duty Trucks					
Gas	0.6	0.7	0.8	1.0	1.1
Diesel	5.3	5.5	5.7	6.8	8.5
Off-Road Diesel					
Construction	0.4	0.2	0.4	0.4	0.4
Agriculture	0.1	0.1	0.1	0.1	0.2
Railroads	0.9	-	-	-	-
Other	5.8	6.0	6.9	7.7	8.2
Other	2.6	3.0	3.0	3.1	3.2
Fuel Combustion					
Residential	0.8	0.8	0.8	0.8	0.8
Commercial	0.4	0.4	0.3	0.3	0.3
Industrial					
Natural Gas	-	-	-	-	-
Other	2.4	3.2	3.3	3.7	4.3
Power Generation	5.3	6.0	5.6	5.8	5.8
Industrial Processes	1.3	1.3	1.6	1.7	1.7
Incineration/Miscellaneous	0.4	0.4	0.5	0.5	0.5
T O T A L	35.1	35.9	36.4	38.8	41.9

TABLE 2.2.3
NO_X PROJECTIONS - PRINCE EDWARD ISLAND
(Kilotonnes)

PROVINCE: Prince Edward Island

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	1.9	1.6	1.3	1.2	1.3
Light-Duty Trucks					
Gas	0.7	0.8	0.9	0.8	0.7
Diesel	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Heavy-Duty Trucks					
Gas	0.2	0.2	0.2	0.3	0.3
Diesel	1.4	1.5	1.5	1.8	2.3
Off-Road Diesel					
Construction	0.1	0.1	0.2	0.2	0.2
Agriculture	0.3	0.4	0.5	0.6	0.6
Railroads	0.1	0.2	0.2	0.2	0.2
Other	0.3	0.3	0.4	0.4	0.4
Other	0.3	0.3	0.3	0.3	0.3
Fuel Combustion					
Residential	0.4	0.4	0.4	0.4	0.4
Commercial	0.1	0.1	0.1	0.1	0.1
Industrial					
Natural Gas	-	-	-	-	-
Other	< 0.1	< 0.1	< 0.1	< 0.1	0.1
Power Generation	0.1	0.1	0.1	0.1	0.1
Industrial Processes	-	-	-	-	-
Incineration/Miscellaneous	0.1	0.1	0.1	0.1	0.1
T O T A L	6.0	6.1	6.2	6.5	7.1

TABLE 2.2.4
NO_X PROJECTIONS - NOVA SCOTIA
(Kilotonnes)

PROVINCE: Nova Scotia

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	12.8	10.9	8.6	8.1	8.6
Light-Duty Trucks					
Gas	5.6	6.3	6.4	5.9	5.5
Diesel	0.2	0.2	0.2	0.3	0.4
Heavy-Duty Trucks					
Gas	1.0	1.2	1.4	1.6	1.8
Diesel	12.1	12.5	13.2	15.7	19.4
Off-Road Diesel					
Construction	0.7	0.6	0.6	0.7	0.8
Agriculture	0.7	1.0	1.2	1.4	1.6
Railroads	4.3	6.6	7.1	7.6	8.1
Other	8.3	8.4	9.8	10.9	11.6
Other	2.1	2.4	2.5	2.5	2.6
Fuel Combustion					
Residential	1.8	1.8	1.7	1.6	1.6
Commercial	1.2	1.0	0.9	0.9	0.8
Industrial					
Natural Gas	-	-	-	-	-
Other	2.9	3.4	3.6	4.0	4.6
Power Generation	21.7	25.2	26.7	26.8	27.1
Industrial Processes	1.6	1.7	1.8	2.0	2.1
Incineration/Miscellaneous	0.5	0.7	0.7	0.8	0.9
T O T A L	77.5	83.9	86.4	90.8	97.5

TABLE 2.2.5
NO_X PROJECTIONS - NEW BRUNSWICK
(Kilotonnes)

PROVINCE: New Brunswick

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	9.7	8.3	6.6	6.2	6.6
Light-Duty Trucks					
Gas	4.5	5.1	5.2	4.7	4.4
Diesel	0.2	0.2	0.2	0.2	0.3
Heavy-Duty Trucks					
Gas	0.8	1.0	1.1	1.3	1.5
Diesel	8.3	8.6	9.1	10.8	13.4
Off-Road Diesel					
Construction	0.5	0.6	0.6	0.6	0.7
Agriculture	0.5	0.7	0.9	1.0	1.2
Railroads	2.5	3.9	4.2	4.5	4.8
Other	3.5	3.6	4.1	4.6	4.9
Other	0.8	0.8	0.8	0.8	0.9
Fuel Combustion					
Residential	1.0	1.0	1.0	1.0	1.0
Commercial	0.6	0.5	0.5	0.5	0.4
Industrial					
Natural Gas	-	-	-	-	-
Other	3.9	4.8	5.0	5.5	6.3
Power Generation	7.9	22.7	31.6	36.7	39.2
Industrial Processes	2.7	3.1	3.4	3.7	4.0
Incineration/Miscellaneous	1.1	1.5	1.6	1.8	1.9
T O T A L	48.5	66.4	75.9	83.9	91.5

TABLE 2.2.6
NO_X PROJECTIONS - QUEBEC
(Kilotonnes)

PROVINCE: Quebec

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	86.6	74.1	58.6	54.9	58.6
Light-Duty Trucks					
Gas	11.8	13.4	13.5	12.4	11.7
Diesel	0.4	0.4	0.5	0.6	0.8
Heavy-Duty Trucks					
Gas	2.9	3.4	4.0	4.5	5.1
Diesel	27.2	28.2	29.7	35.3	43.7
Off-Road Diesel					
Construction	3.6	4.3	4.9	5.2	5.5
Agriculture	4.4	5.4	5.8	6.2	6.7
Railroads	17.9	14.6	15.7	16.6	17.8
Other	21.1	24.6	26.3	27.5	28.1
Other	16.4	17.3	18.0	18.6	19.9
Fuel Combustion					
Residential	7.5	6.1	5.3	4.5	4.1
Commercial	3.9	4.7	4.7	4.6	4.6
Industrial					
Natural Gas	-	-	-	-	-
Other	21.3	24.6	26.0	28.0	29.4
Power Generation	1.5	1.9	3.3	3.3	3.3
Industrial Processes	6.8	7.8	8.8	10.0	11.3
Incineration/Miscellaneous	6.0	7.3	8.2	9.0	10.1
T O T A L	239.3	238.1	233.3	241.2	260.7

TABLE 2.2.7
NO_X PROJECTIONS - ONTARIO
(Kilotonnes)

PROVINCE: Ontario

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	145.8	122.2	96.5	90.5	96.6
Light-Duty Trucks					
Gas	36.8	40.2	40.7	37.3	35.1
Diesel	1.5	1.3	1.5	1.9	2.3
Heavy-Duty Trucks					
Gas	7.5	8.7	10.0	11.4	13.0
Diesel	88.8	87.9	92.7	110.0	136.4
Off-Road Diesel					
Construction	9.1	10.9	13.7	17.1	21.5
Agriculture	7.4	7.5	8.0	8.2	8.6
Railroads	32.1	33.1	35.6	37.7	40.4
Other	27.2	31.7	34.7	34.9	34.3
Other	20.2	22.1	23.1	23.7	24.5
Fuel Combustion					
Residential	15.4	14.6	15.0	15.4	15.3
Commercial	9.7	9.5	10.4	10.5	11.0
Industrial					
Natural Gas	0.5	0.5	0.6	0.6	0.6
Other	45.1	50.1	58.2	63.7	70.5
Power Generation*	97.6	74.9	83.4	114.6	94.8
Industrial Processes	38.2	40.5	47.6	54.2	62.3
Incineration/Miscellaneous	2.5	2.7	2.8	2.9	2.9
T O T A L	585.4	578.4	574.5	634.6	670.1

* Ontario Hydro is developing a plan to reduce NOx emissions which is expected to be available in the fall of 1989.

TABLE 2.2.8
NO_X PROJECTIONS - MANITOBA
(Kilotonnes)

PROVINCE: Manitoba

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	17.9	15.3	12.1	11.3	12.1
Light-Duty Trucks					
Gas	8.2	9.2	9.4	8.6	8.1
Diesel	0.3	0.3	0.3	0.4	0.5
Heavy-Duty Trucks					
Gas	1.5	1.8	2.1	2.4	2.7
Diesel	15.3	15.9	16.8	19.9	24.7
Off-Road Diesel					
Construction	1.4	1.9	1.9	2.2	2.6
Agriculture	5.2	6.1	7.0	7.0	7.2
Railroads	18.2	19.6	21.0	22.3	23.9
Other	3.7	5.7	6.3	6.6	7.0
Other	4.3	4.3	4.3	4.4	4.6
Fuel Combustion					
Residential	1.5	1.3	1.3	1.3	1.3
Commercial	1.3	1.2	1.3	1.4	1.4
Industrial					
Natural Gas	-	-	-	-	-
Other	2.2	2.2	2.5	2.8	3.3
Power Generation	2.7	1.6	1.6	0.7	0.7
Industrial Processes	0.6	0.6	0.7	0.8	0.9
Incineration/Miscellaneous	0.4	0.4	0.4	0.5	0.5
T O T A L	84.7	87.4	89.0	92.6	101.5

TABLE 2.2.9
NO_X PROJECTIONS - SASKATCHEWAN
(Kilotonnes)

PROVINCE: Saskatchewan

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	13.5	11.6	9.1	8.6	9.1
Light-Duty Trucks					
Gas	11.6	13.2	13.4	12.2	11.5
Diesel	0.4	0.4	0.5	0.6	0.8
Heavy-Duty Trucks					
Gas	2.5	2.9	3.4	3.8	4.3
Diesel	22.9	23.7	25.0	29.7	36.8
Off-Road Diesel					
Construction	2.6	2.5	2.6	2.9	3.4
Agriculture	14.9	17.6	19.0	21.0	23.5
Railroads	10.2	8.8	9.4	10.0	10.7
Other	7.4	8.5	9.6	10.3	10.4
Other	9.5	8.6	8.1	8.1	8.7
Fuel Combustion					
Residential	2.3	2.0	2.1	2.2	2.2
Commercial	1.1	1.1	1.3	1.4	1.5
Industrial					
Natural Gas	16.9	19.6	21.5	22.2	22.1
Other	4.8	4.5	5.1	5.8	6.4
Power Generation	36.1	43.6	47.8	45.6	44.0
Industrial Processes	0.9	1.0	1.1	1.2	1.4
Incineration/Miscellaneous	0.5	0.6	0.7	0.8	0.8
T O T A L	158.1	170.2	179.7	186.4	197.7

TABLE 2.2.10
NO_X PROJECTIONS - ALBERTA
(Kilotonnes)

PROVINCE: Alberta

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	44.9	38.5	30.4	28.5	30.4
Light-Duty Trucks					
Gas	15.1	17.2	17.4	15.9	15.0
Diesel	0.5	0.6	0.6	0.8	1.0
Heavy-Duty Trucks					
Gas	3.2	3.8	4.4	5.0	5.7
Diesel	31.7	32.9	34.7	41.2	51.0
Off-Road Diesel					
Construction	8.1	6.3	6.4	7.4	8.8
Agriculture	17.1	20.6	21.1	22.3	24.0
Railroads	35.8	40.0	43.0	45.5	48.8
Other	25.2	21.9	26.0	29.5	30.9
Other	14.9	13.8	13.5	13.9	14.5
Fuel Combustion					
Residential	7.0	5.9	6.2	6.5	6.6
Commercial	4.5	4.5	4.8	5.1	5.2
Industrial					
Natural Gas	131.5	124.9	118.4	100.3	76.7
Other	11.3	13.8	18.0	18.4	19.0
Power Generation	68.1	106.3	112.7	122.4	127.0
Industrial Processes	26.2	21.8	25.6	31.3	39.3
Incineration/Miscellaneous	1.5	2.4	2.6	2.9	3.2
T O T A L	446.6	465.2	485.8	496.9	507.1

TABLE 2.2.11
NO_X PROJECTIONS - BRITISH COLUMBIA
(Kilotonnes)

PROVINCE: British Columbia

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	51.2	43.8	34.6	32.5	34.6
Light-Duty Trucks					
Gas	24.5	27.8	28.2	25.9	24.3
Diesel	0.8	0.9	1.0	1.3	1.6
Heavy-Duty Trucks					
Gas	4.6	5.4	6.3	7.1	8.1
Diesel	45.6	47.3	49.9	59.2	73.4
Off-Road Diesel					
Construction	4.0	3.7	3.7	3.9	4.2
Agriculture	2.9	5.3	6.5	6.9	7.3
Railroads	17.8	17.1	18.3	19.4	20.8
Other	37.2	33.7	37.9	41.2	44.2
Other	6.7	8.2	8.4	8.6	9.2
Fuel Combustion					
Residential	3.6	3.2	3.2	3.3	3.3
Commercial	2.7	2.6	2.8	2.8	2.9
Industrial					
Natural Gas	9.9	10.3	12.0	12.9	13.1
Other	25.3	25.1	28.7	31.6	34.8
Power Generation	3.7	1.0	1.0	1.0	1.2
Industrial Processes	10.7	12.1	13.4	14.9	16.7
Incineration/Miscellaneous	11.3	11.1	11.6	12.6	13.7
T O T A L	262.5	258.6	267.5	285.1	313.4

TABLE 2.2.12
NO_X PROJECTIONS - YUKON/NORTHWEST TERRITORIES
(Kilotonnes)

PROVINCE: Yukon/Northwest Territories

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	0.6	0.5	0.4	0.4	0.4
Light-Duty Trucks					
Gas	1.0	1.1	1.1	1.0	1.0
Diesel	< 0.1	< 0.1	< 0.1	0.1	0.1
Heavy-Duty Trucks					
Gas	0.2	0.2	0.3	0.3	0.3
Diesel	2.2	2.3	2.4	2.8	3.5
Off-Road Diesel					
Construction	0.8	0.9	1.0	1.1	1.3
Agriculture	< 0.1	0.1	0.1	0.1	0.1
Railroads	0.1	0.1	0.1	0.2	0.2
Other	5.9	5.3	6.0	6.5	7.0
Other	1.6	2.0	2.1	2.2	2.3
Fuel Combustion					
Residential	0.2	0.2	0.2	0.2	0.2
Commercial	0.3	0.3	0.2	0.2	0.2
Industrial					
Natural Gas	-	-	-	-	-
Other	0.2	0.1	0.1	0.2	0.2
Power Generation	3.2	4.4	5.4	6.9	8.5
Industrial Processes	-	-	-	-	-
Incineration/Miscellaneous	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
T O T A L	16.3	17.5	19.4	22.2	25.3

FIGURE 2.2.1

NOX EMISSIONS:1985-2005
CANADA

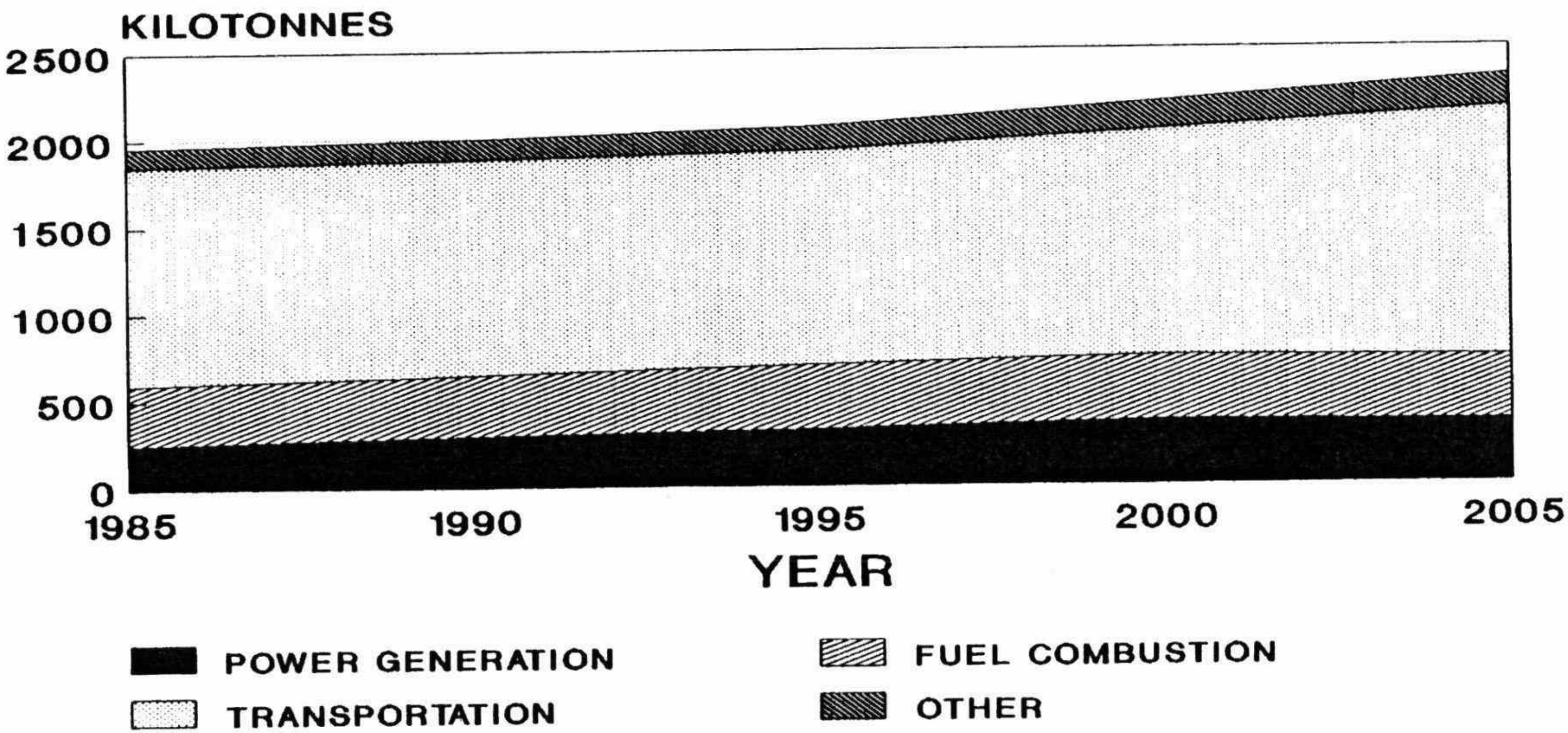


FIGURE 2.2.2

NOX EMISSIONS:1985-2005
NEWFOUNDLAND

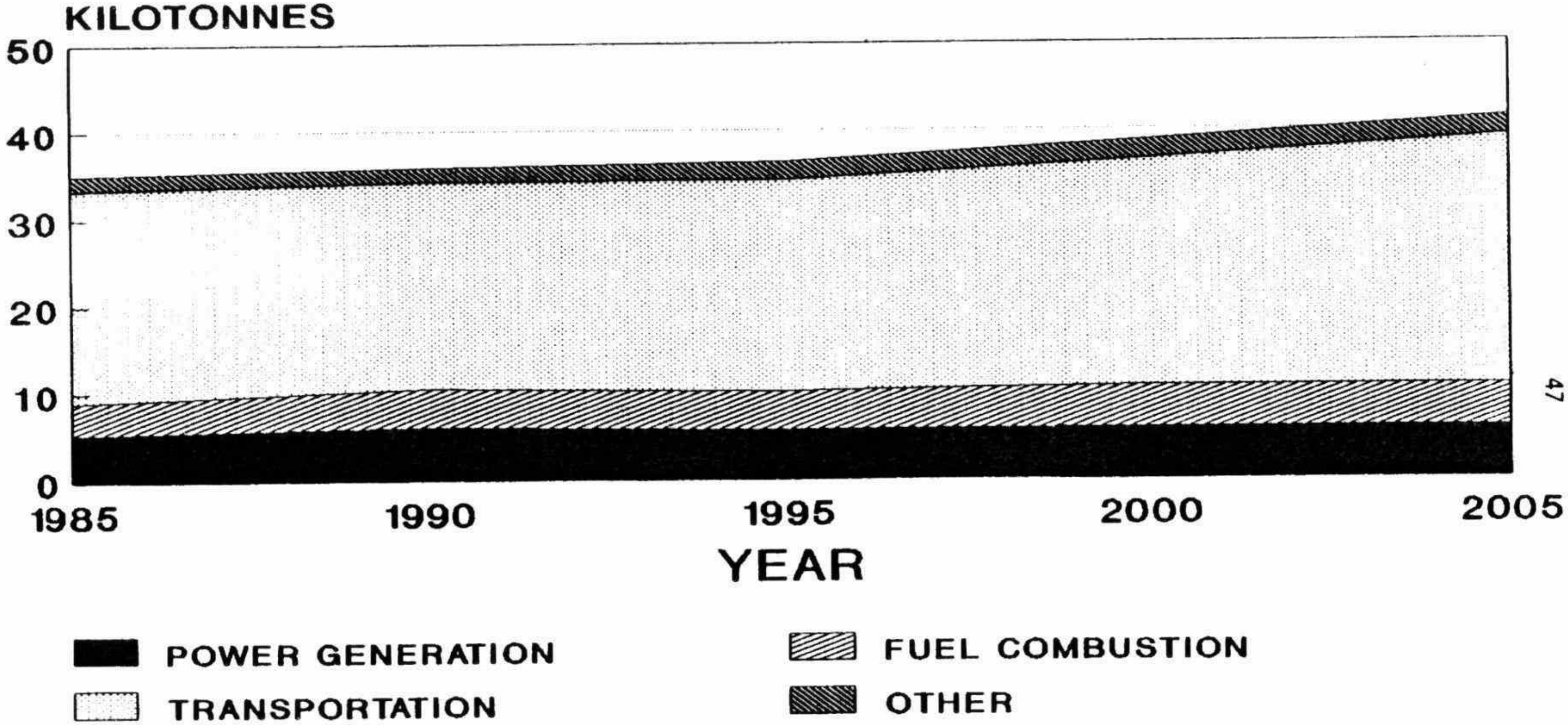


FIGURE 2.2.3

NOX EMISSIONS:1985-2005
PRINCE EDWARD ISLAND

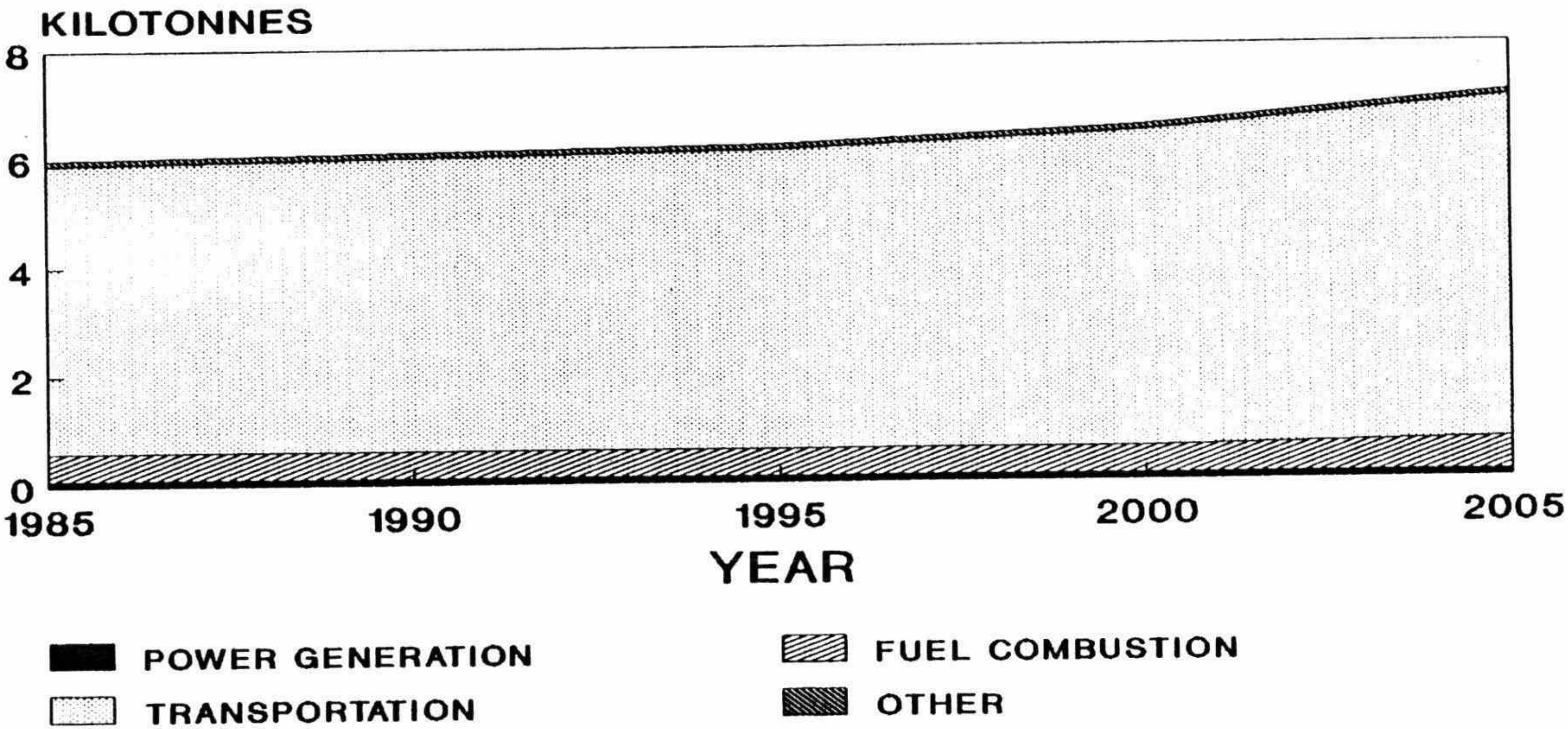


FIGURE 2.2.4

NOX EMISSIONS:1985-2005
NOVA SCOTIA

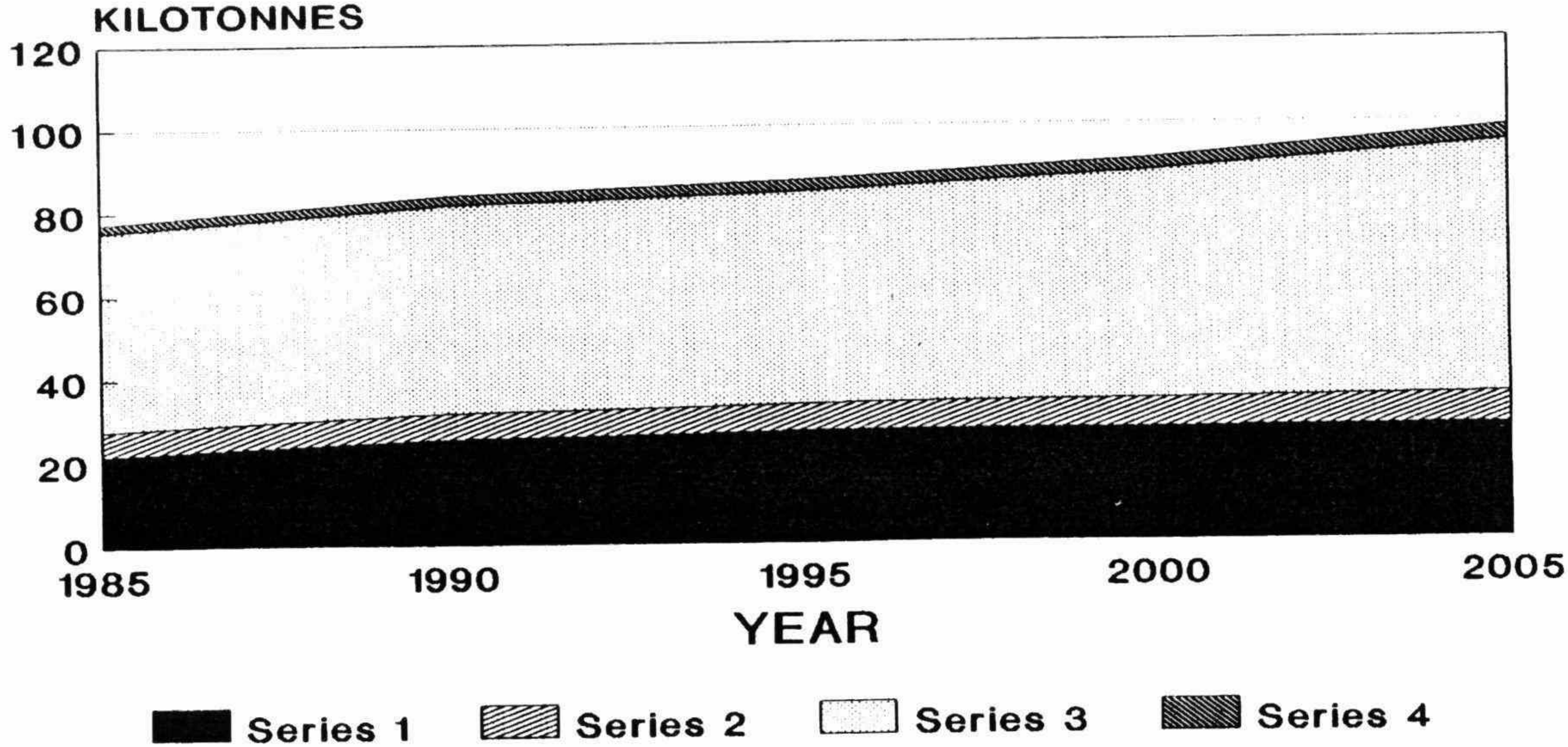


FIGURE 2.2.5

NOX EMISSIONS:1985-2005
NEW BRUNSWICK

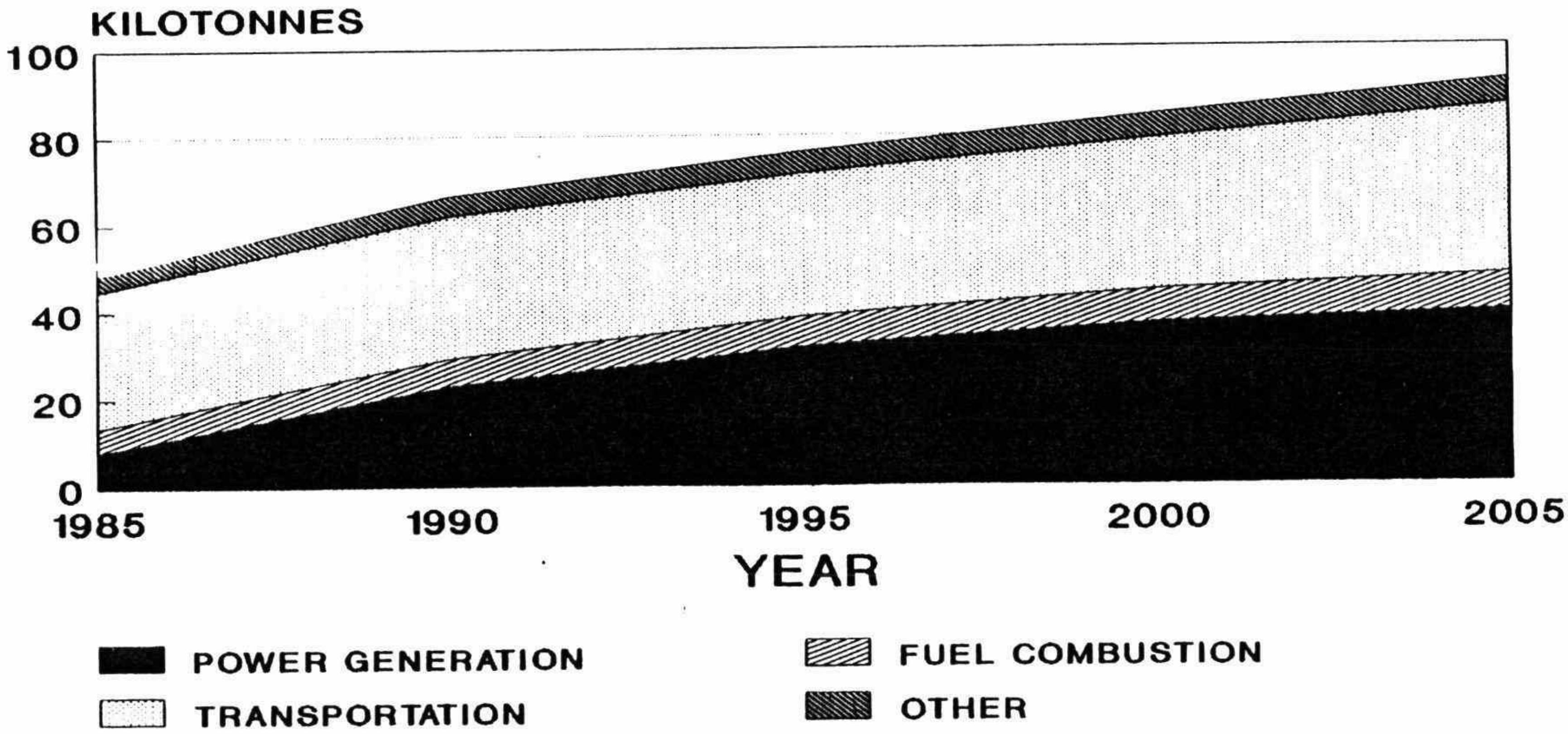


FIGURE 2.2.6

NOX EMISSIONS:1985-2005
QUEBEC

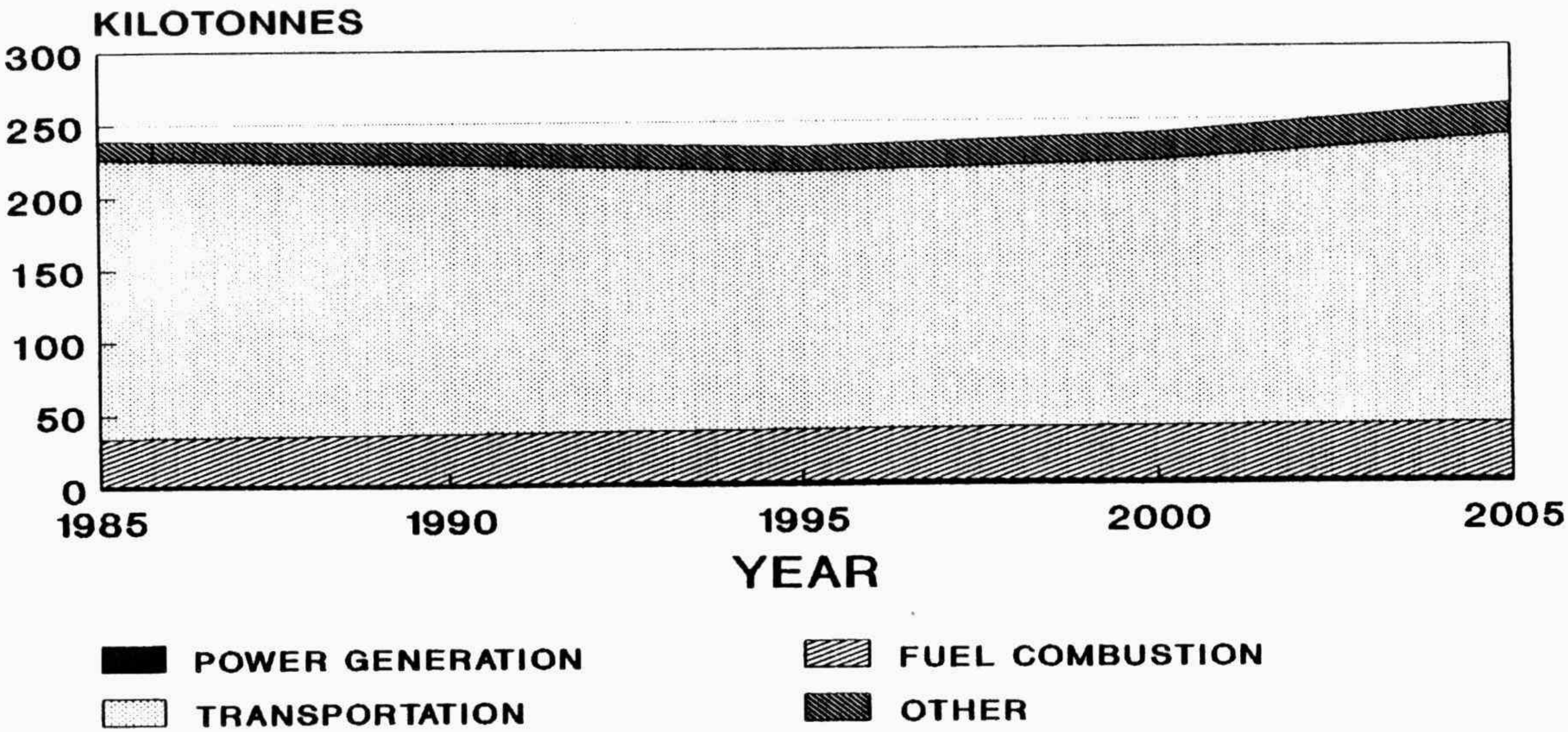


FIGURE 2.2.7

NOX EMISSIONS:1985-2005
ONTARIO

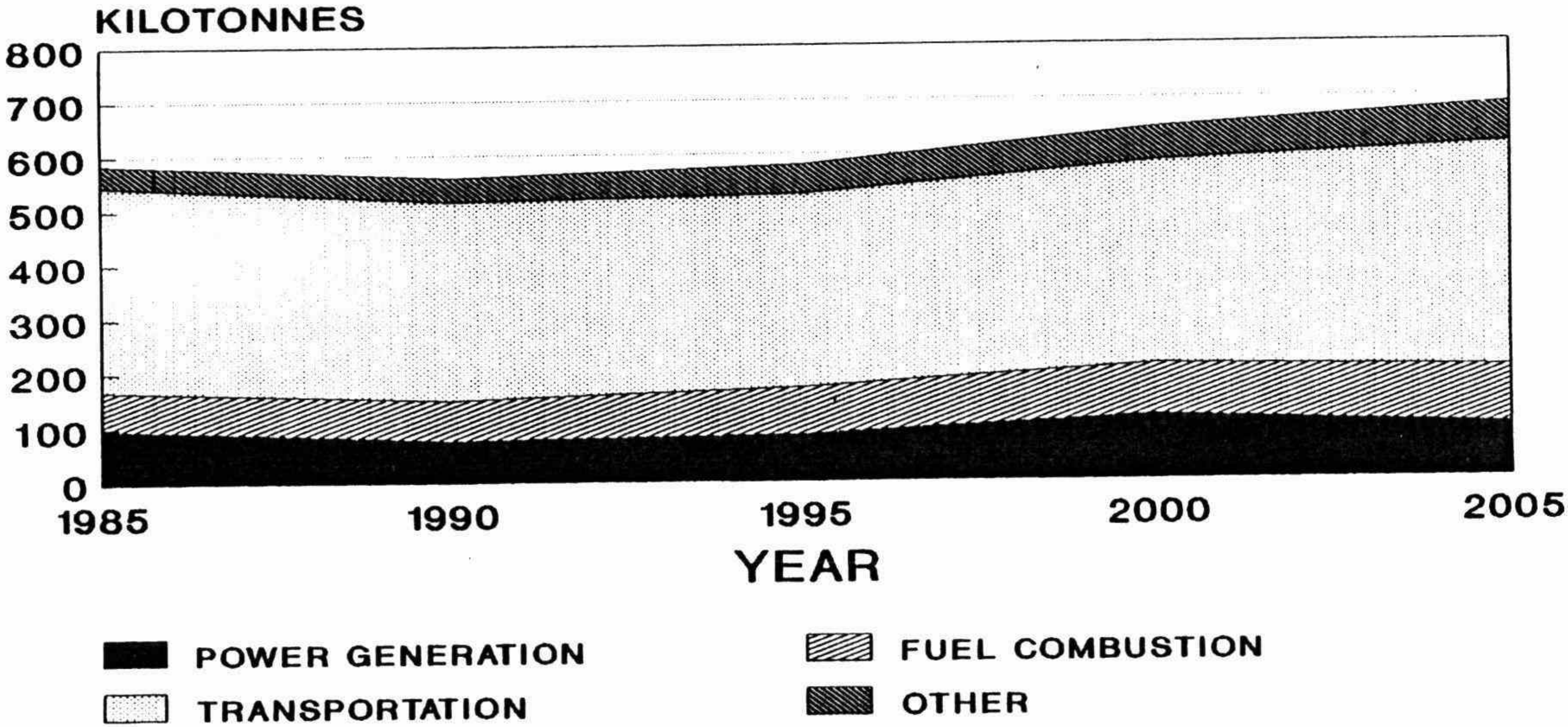


FIGURE 2.2.8

NOX EMISSIONS:1985-2005
MANITOBA

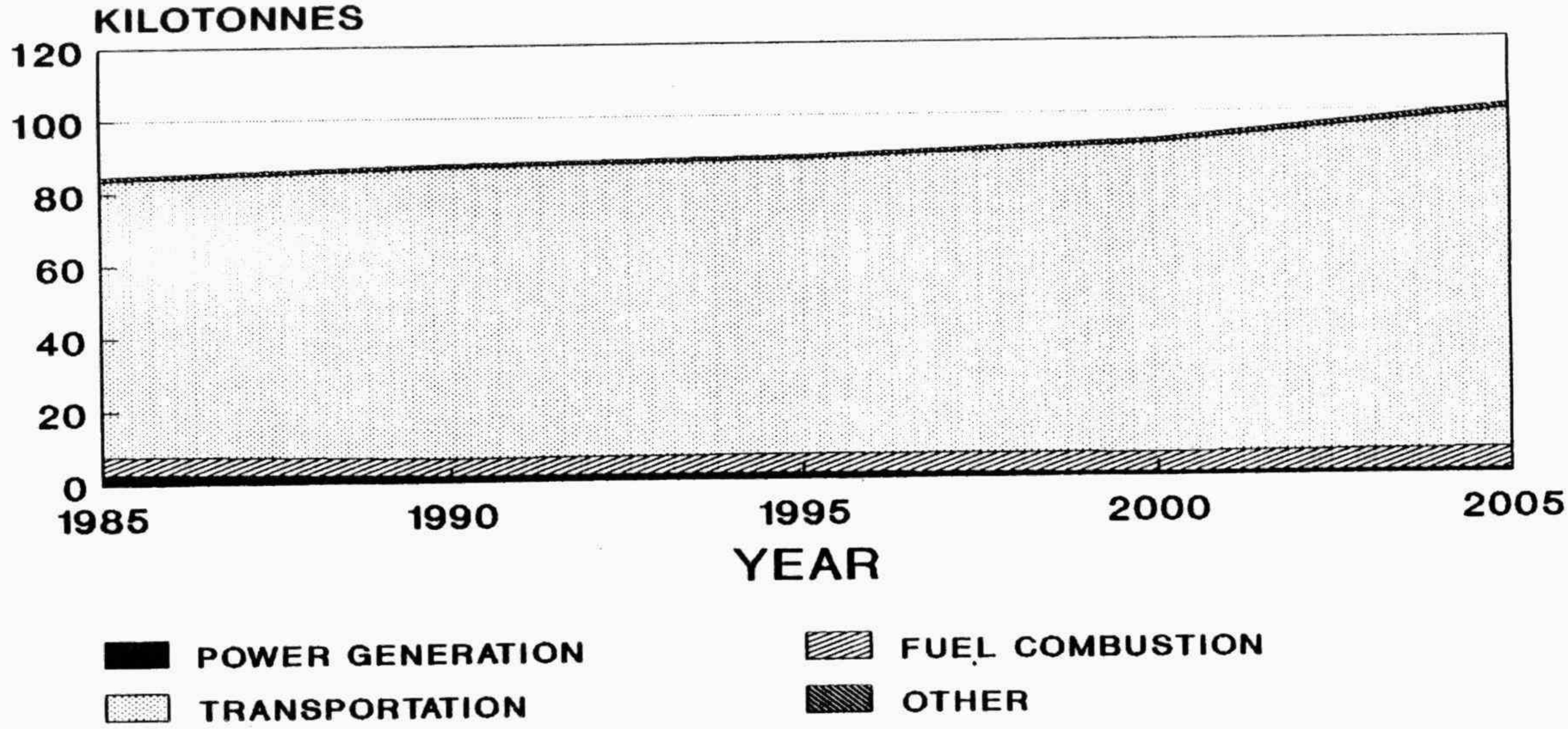


FIGURE 2.2.9

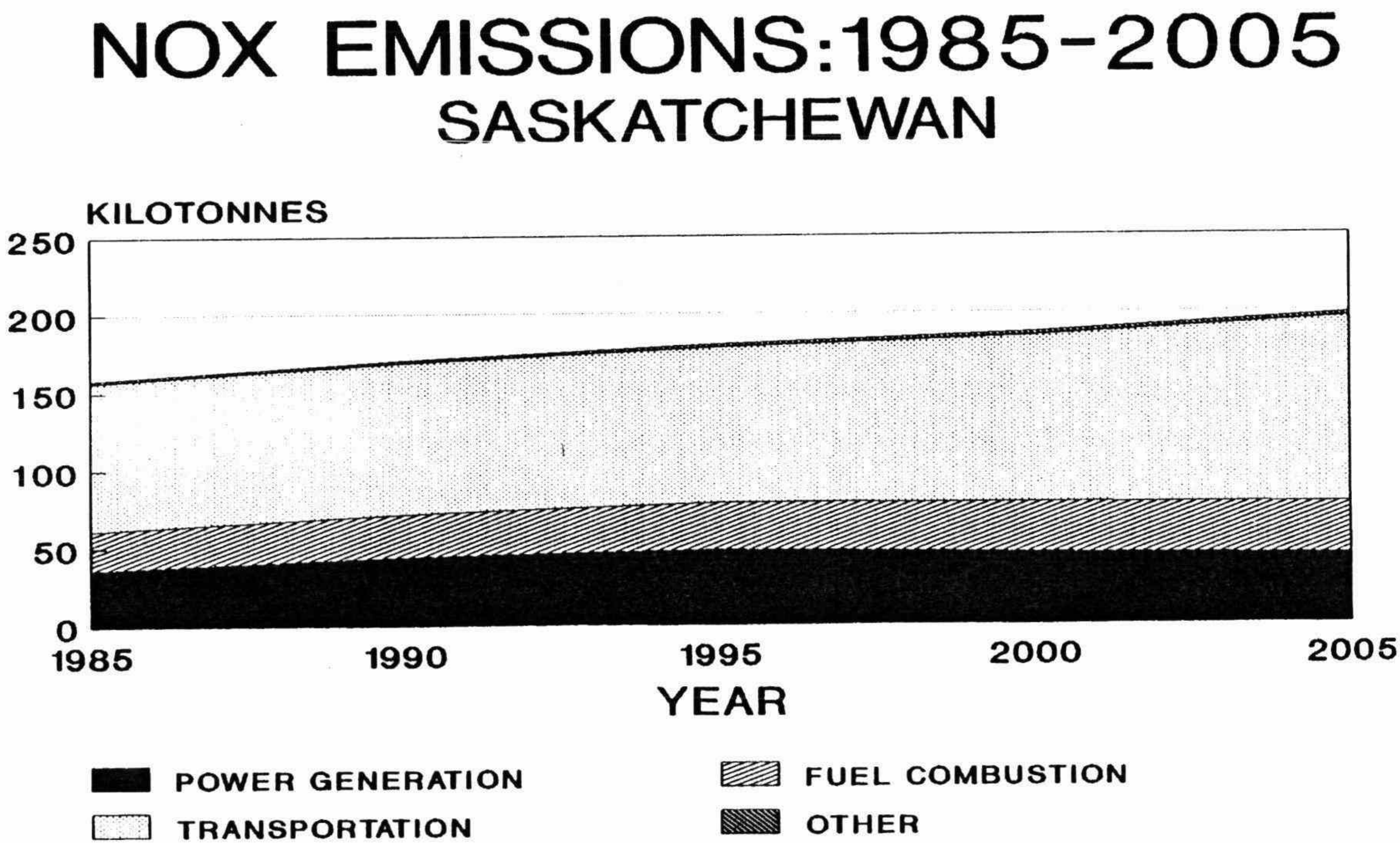

NOX EMISSIONS:1985-2005
SASKATCHEWAN
KILOTONNES
250
200
150
100
50
0
1985
1990
1995
2000
2005
YEAR
POWER GENERATION
FUEL COMBUSTION
TRANSPORTATION
OTHER

FIGURE 2.2.10

NOX EMISSIONS:1985-2005
ALBERTA

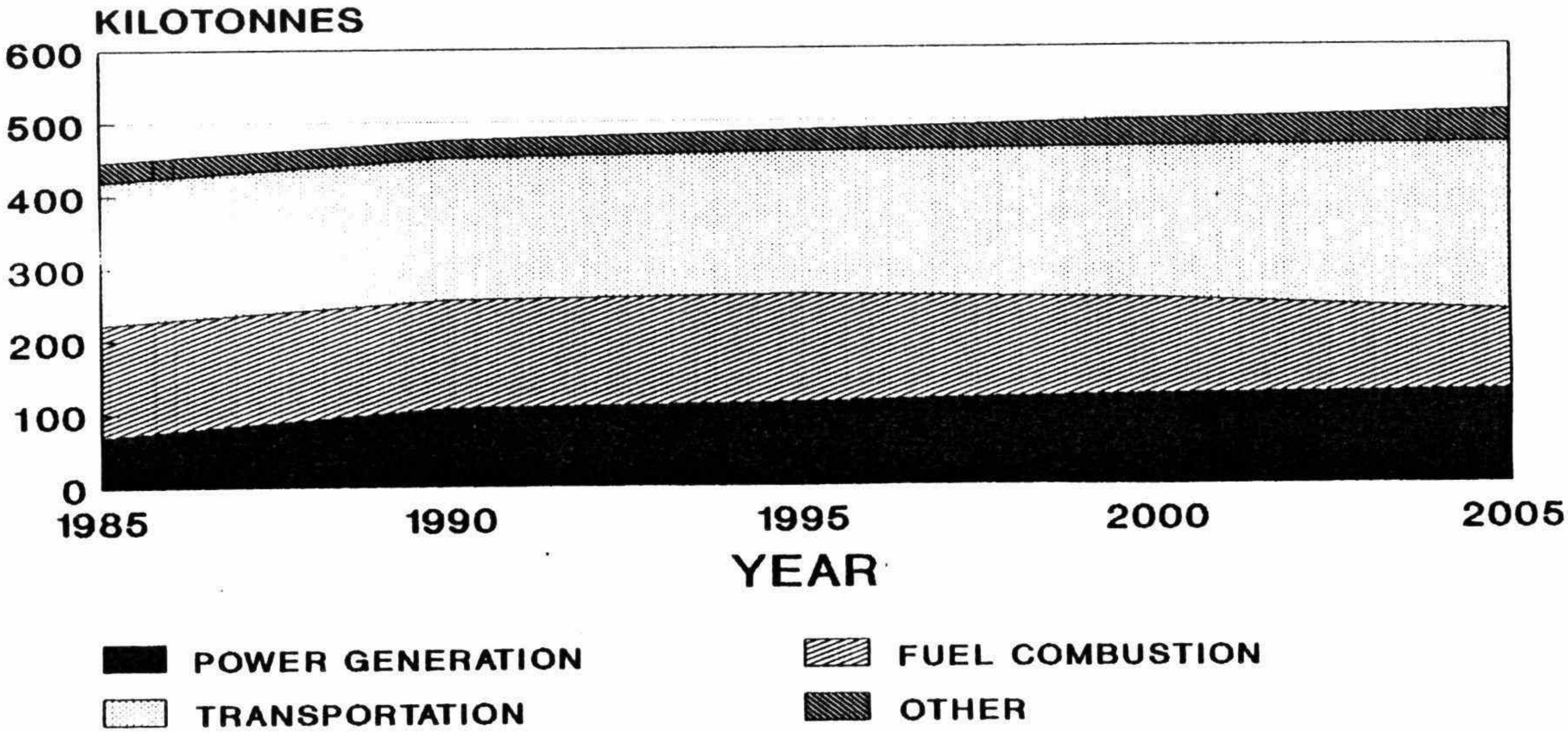


FIGURE 2.2.11

NOX EMISSIONS:1985-2005
BRITISH COLUMBIA

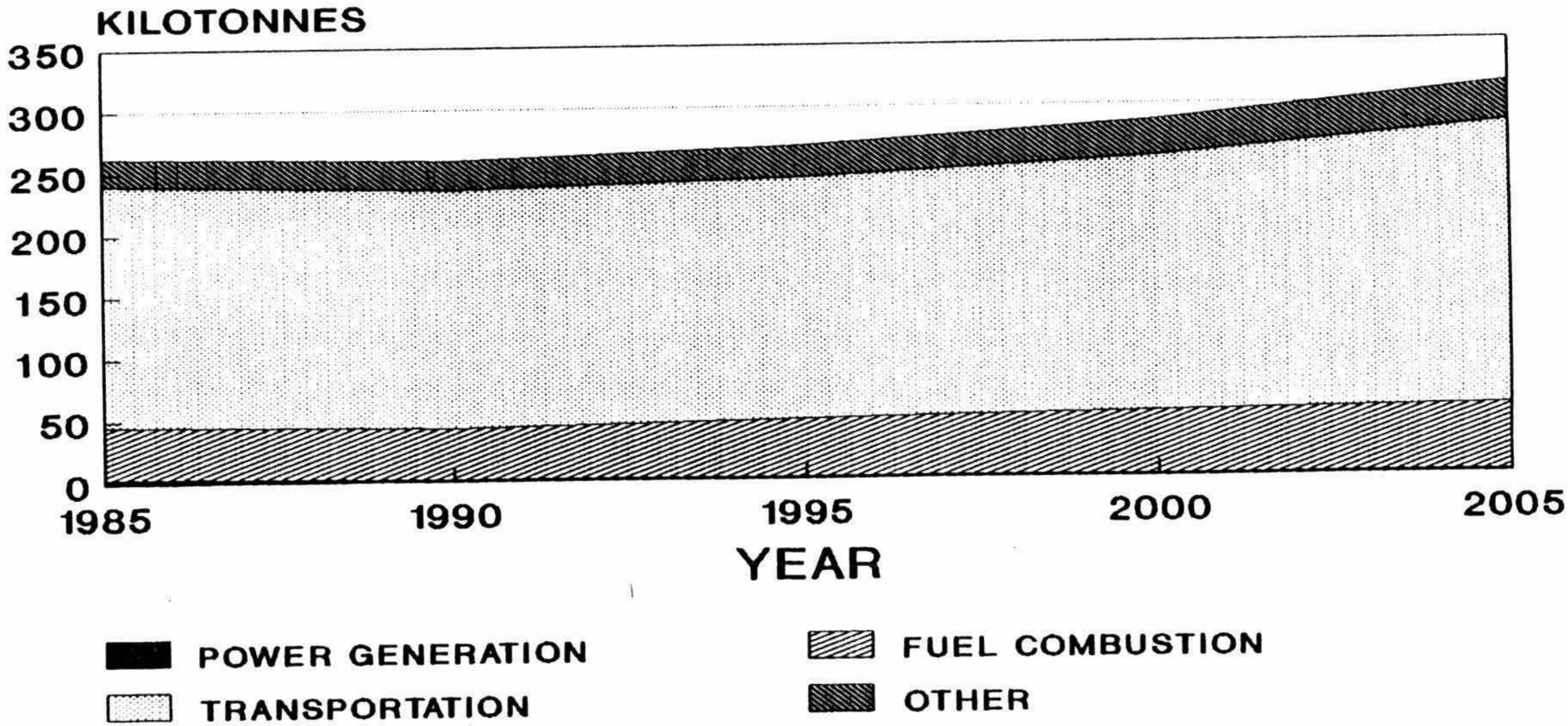
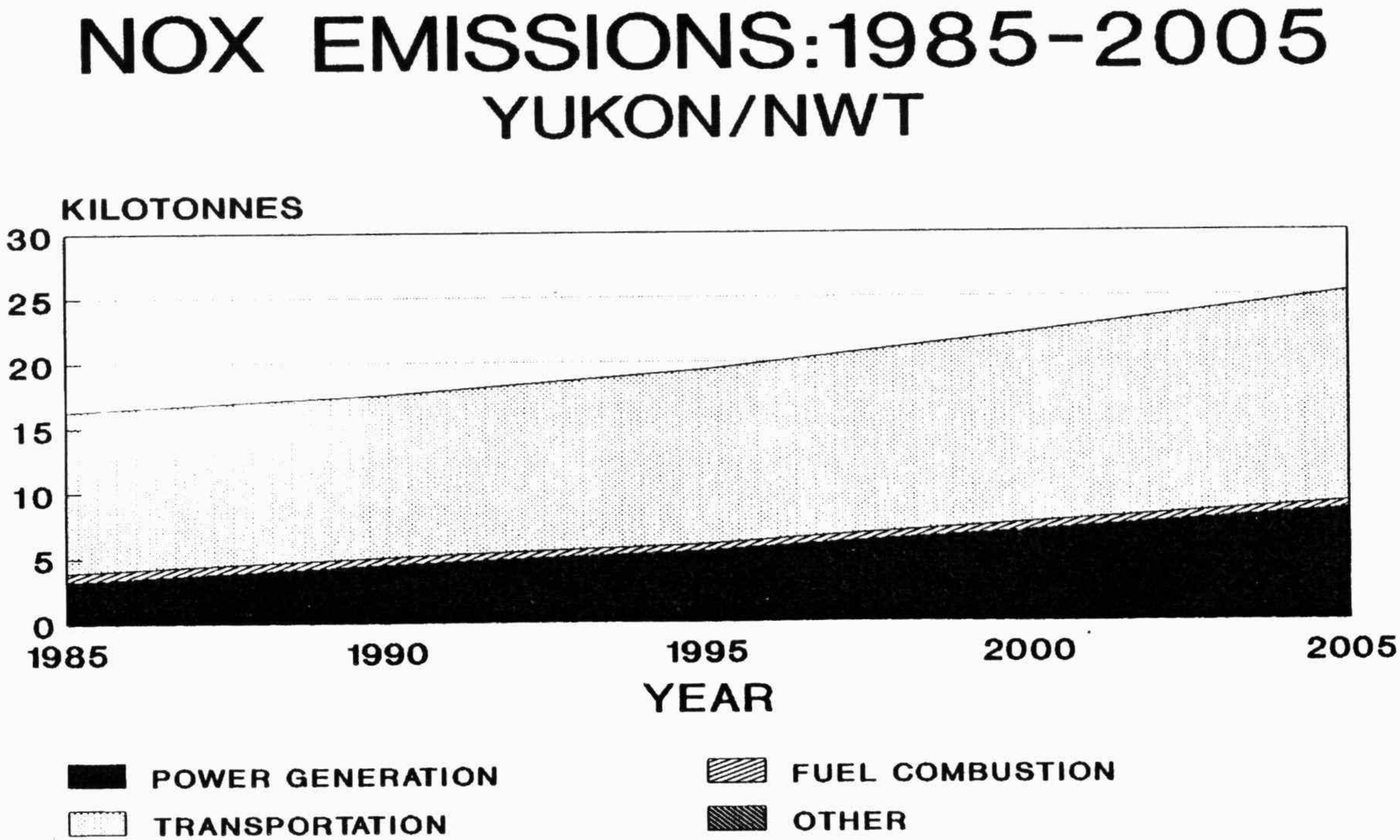


FIGURE 2.2.12


NOX EMISSIONS:1985-2005
YUKON/NWT
KILOTONNES
30
25
20
15
10
5
0
1985
1990
1995
2000
2005
YEAR
POWER GENERATION
FUEL COMBUSTION
TRANSPORTATION
OTHER

APPENDIX A

NOx Emission Projections

A. Base Year: 1985

Sources of Data (base year):

- motor vehicles
  - population
    - Statistics Canada
    - Transportation Systems Division (TSD), Env. Canada
  - emission factors - TSD
  - vehicle miles travelled - TSD
- other transportation
  - fuel consumption - Statistics Canada
  - emission factors - U.S. EPA (AP-42)
- fuel combustion
  - fuel consumption - Statistics Canada
  - emission factors - U.S. EPA
  - petroleum refineries:
    - emissions - provided by refineries and provinces
    - fuel consumption - supplied by refineries and provinces
    - emission factors - U.S. EPA
  - natural gas processing:
    - emissions obtained directly from provincial agencies (also: fuel consumption)
- power generation
  - emissions - generally supplied by provincial utilities and power commissions (also includes fuel consumption)
  - additional emissions from small stations and gas turbines calculated from fuel consumption data and U.S. EPA emission factors
- industrial processes:
  - emissions data from 1985 inventory
  - data generated either through provincial agencies (point sources) or Statistics Canada production figures
- incineration/miscellaneous:
  - emissions calculated by use of Statistics Canada data with emission factors

B. Forecast Years: 1986-2005

Sources of data:

- motor vehicles
  - emission factors - TSD
  - growth in car/truck stock - National Energy Board (NEB) 1988 report
    - (not province - specific)
  - assume no change in vehicle miles travelled

- other transportation
  - growth in energy consumption (e.g. 1987 vs. 1985 values) - NEB
  - province-specific statistics
  - assume no change in emission factors or level of control technology available

- fuel combustion
  - industrial/commercial/residential
    - growth in energy consumption (for each fuel) - NEB
  - province-specific statistics
  - assume no change in emission factors or level of control technology available

- petroleum refineries (fuel combustion)
  - growth in Energy consumption (NEB)
  - no changes in emission factors or level of control technology

- natural gas processing (fuel combustion)
  - Informetrica GDP growth rates for "Petroleum & gas-resource extraction"
  - assumes decrease in NOx emissions in Alberta at a rate of 3%/year starting in 1991 (45% by the year 2005)

- power generation
  - emissions forecasts obtained from various provincial utilities and from Oil, Gas & Energy Division, Env. Canada simulation model (CANSIM)

- industrial processes
  - Informetrica GDP growth rates used for following sectors:

    *nitric acid - "Chemicals"
    *nitrate fertilizer - "Chemicals"
    *metallurgical coke - "Petroleum & coal products - manufacturing"
    *aluminum production - "Primary metals"
    *sulphate pulping - "Pulp & paper"
    *tar sands - "Mining services"

  - growth en Energy consumption (NEB) for petroleum refineries
  - data for growth rates are province-specific

- incineration/miscellaneous
  - population growth rates for growth in incineration practices
  - wigwam burners - Informetrica GDP growth rates - "Wood manufacturing"
  - slash burning - "Informetrica GDP growth rates - "Forestry"

Note: All growth rates are for a "high growth" scenario as forecast by the NEB (1988). Informetrica growth rates are based on the most recent tabulations from their economic model (TIM).

REPORT NO 2.3

NOx CONTROL TECHNOLOGIES

Prepared for:

Federal Provincial Advisory Committee
on Air Quality

Conservation and Protection
Environment Canada

July 1989

2.3 NOx CONTROL TECHNOLOGIES

2.3.1 Introduction

This report summarizes existing NOx control technologies for both mobile and stationary sources. It also presents preliminary estimates of NOx reduction potential and cost if selected technologies were applied consistently across the country to the various source sectors. Emission reduction potential and costs are presented nationally and province by province for each of the source sectors or control options.

The information provided is preliminary and intended only to give some initial guidance on NOx reduction opportunities and cost-effectiveness of selected options. The reduction potential and costs presented in the descriptive parts of the report have been extracted from readily available reference sources. Since there is a desire to understand the potential implications of NOx control on emissions of other pollutants, a rough estimate of the effect of each NOx control technology on emissions of SO_2, VOCs and CO_2 is also provided where possible.

Only selected technologies are included in the summary tables at the end of the report. For some sources, other technologies could be applied to achieve lower or intermediate levels of NOx removal with a different cost effectiveness. Those technologies presented in the tables should not be interpreted as preferred technologies but are presented to indicate the range of NOx reduction possible and generally include a high efficiency (and sometimes high cost) removal technology for each sector. In a more detailed sectoral or regional analyses, other possible technologies should also be examined in selecting a control level or plan.

In the summary tables, dates were arbitrarily selected in some cases for when a control measure was assumed to become effective. This was done to enable the distinction between new source and existing source (retrofit) controls. The choice of effective date for a control

measure affects the reduction potential in year 2005 and the annual cost for that measure.

Overall, the information presented is intended to provide preliminary national, regional and sectoral pictures on NOx control opportunities and provide a common basis for all stakeholders to begin discussion on a Canadian NOx control strategy or plan. The national picture will be re-examined and re-presented periodically during the course of discussions as preferred control options are identified.

2.3.2 Technology Descriptions

A. MOBILE SOURCES

1. New Light Duty Gasoline Vehicles (LDGV) Standards

[Canadian light duty vehicle NOx standard: 1 g/mile effective 87-09-01. Canadian light duty truck standard: 1.2 to 1.7 g/m depending on loaded vehicle weigh]

Reducing the NOx emission standards for LDGVs to 0.4 g/mi. for automobiles and to 0.4 to 1.5 g/mi for trucks as adopted in California would not involve the use of new technology. It would require higher precious metal loading of three-way catalysts, better air-fuel ratio control and better control of exhaust gas recirculation. Better air-fuel ratio control can be achieved through changes in engine computer software and through greater use of fuel injection.
The cost and benefits of this proposal are preliminary. The cost of adopting tighter standards for NOx cannot be separated from that for other pollutants. Adopting California NOx standards would mean that Canada would get the same vehicles as California which are required to meet a number of provisions which are stricter than the federal requirements. The cost differential in adopting more California standards

could change because of stricter U.S. federal standards, the larger number of states requiring California standards and changes in certification and compliance procedures.

Tighter standards should not have any effect on fuel consumption.

- NOx reduction potential 90%
- VOC reduction potential 95%
- SO_2 reduction potential 0
- CO_2 reduction potential 0
- Status: 0.4 g/mi. NOx standard adopted in California for phase-in over 1989 to 1992 period. 0.25 g/mi. NMHC standard adopted for phase-in over 1991 to 1997 period
- Cost: $90/vehicle (total cost of $180 for both HC and NOx reductions)

2. Light Duty Vehicle Inspection and Maintenance (I/M)

The emission control equipment originally installed on new vehicles is designed to function within specification for the "useful life" of the vehicle which is presently defined as 5 years or 50,000 miles. For the latest model vehicles in particular, if a vehicle is maintained in accord with the manufacturer's recommended schedule and not misfuelled, this equipment should operate efficiently for considerably longer than 50,000 miles, thus maintaining NOx emissions, and those of the other regulated pollutants, CO, THC, and particulates, at low levels.

However, clinics and surveys in both Canada and the U.S.A. have shown that between 20 and 50% of the light duty vehicles on the roads may have emissions in excess of the regulated standards. These higher emission result not only from the

rigors of on-road driving, but from the lack of sufficient maintenance and from tampering with vehicle emission control systems. Each province should adopt regulations for in-use motor vehicles which prohibit tampering and, thereby, encourage proper maintenance. Such regulations should be accompanied by some form of enforcement program. Depending upon the severity of the air quality problem, the enforcement programs should include some or all of the following: a pro-controls/anti-tampering publicity campaign, a mechanic/dealer education program, a dealer/mechanic enforcement program, and an inspection and maintenance program (I/M). Regular compulsory I/M inspections are now required in over 50 major urban areas in the U.S.A.

An I/M program should include, as a minimum, an inspection on vehicle re-sale, but could require a compulsory, annual vehicle inspection.

In California, the state government is actively investigating requirements for the standardization of vehicle computer systems (both hardware and software components) and the application of new computerized diagnostics in connection with vehicle inspections and repair. The implementation of these sophisticated techniques could improve repair efficiency, plus reduce repair and inspection time and costs. The result would be less inconvenience for the vehicle owner and a greater likelihood of correct and efficient diagnosis and repair. A reduction in emission of pollutants such as NOx would invariably accompany such innovations.

- NOx reduction potential	5% *
- VOC reduction potential	25%
- SO_2 reduction potential	0
- CO_2 reduction potential	0 to 2.5% (as a result of fuel savings)

- CO reduction potential 30%
- Status: Program requirements, procedures available
- Cost: $15/vehicle/year.

* reduction from present fleet. This reduction is expect ED to increase if tighter NOx standards are adopted. As emission control systems becomes more efficient. The benefits from improved maintenance and reduced tampering increase.

3. Heavy Duty Gasoline Vehicles (HDGVs)

[Canadian HDGV NOx Standard: 6 g/BHP-hr effective 88-12-01]

Gasoline powered heavy duty vehicles utilize exhaust gas recirculation, and ignition timing modifications to reduce NOx emissions. The HDGVs up to 14,000 lbs gross vehicle weight rating (GVWR) usually have an oxidation catalyst to meet the more stringent hydrocarbon and carbon monoxide limits set for these trucks. Three-way catalysts are not as resistant to high temperatures and so cannot be applied to these trucks at this time. Hydrocarbon and carbon monoxide standards for heavy duty trucks above 14,000 lbs GVWR are more lax because catalyst cannot withstand the high exhaust temperatures found in these larger trucks. Although heavy duty gasoline trucks could in theory meet tighter NOx emission standards through the use of three-way catalyst, catalyst life would be too short at the exhaust temperatures encountered. Further reductions in NOx using present technology would cause large increases in fuel consumption.

- NOx reduction potential 0 (5 g/BHP-hr Std already assumed in NOx projections)
- VOC reduction potential 0
- SO_2 reduction potential 0
- CO_2 reduction potential -0.5%
- Status: Available and demonstrated
- Cost:

4. Diesel Engines (On-road, Off-road, Locomotives)

The emission control technology is similar for both on-road and off-road diesel engines and for diesel locomotives. It involves optimization of engine design and operation rather than the application of some new emission cleanup technologies like the 3-way catalysts used for LDV gasoline engines. A complicating factor is that some of the changes in diesel engine operation used to reduce NOx increase particulate emissions. Hence, NOx emission regulations for diesel engines must also be combined with particulate regulations.

NOx and particulate control technologies for diesel engines include:

- turbocharging and aftercooling (not applicable to small engines)
- higher injection pressure
- combustion chamber, air swirl and spray pattern optimization
- injection rate shaping
- exhaust gas recirculation (increases particulates) (not used in heavy duty engines - found on some light duty)
- retarded injection timing (increases fuel consumption and particulates)
- fueling rate control (to reduce particulates)
- particulate traps and/or catalysts (particulate control - probably requires desulphurized fuel - 0.5 - 3% fuel consumption penalty)

Electronics are now being introduced to control injection and turbocharging. Some of the above measures require extensive redesign of diesel engines.

On-road diesel (Heavy Duty Diesel Vehicles - HDDV):

- NOx reduction potential 50%
- VOC reduction potential 0
- SO_2 reduction potential 0
- CO_2 reduction potential 0/-4%
- Status: Available, demonstrated
- Cost:

Off-road diesel (excluding agriculture and construction):

- NOx reduction potential 45-55%
- VOC reduction potential 38%
- SO_2 reduction potential 0
- CO_2 reduction potential 0/-4%
- Status: Available, demonstrated
- Cost: $600-2000/tonne NOx + HC removed.

Diesel locomotive engines:

- NOx reduction potential 55-63%
- VOC reduction potential 52-71%
- SO_2 reduction potential 0
- CO_2 reduction potential 0/-4%
- Status: Available, demonstrated
- Cost: $1100/tonne NOx + HC removed.

B. STATIONARY SOURCES

1. Power Utility and Industrial Boilers

a) Control of Fuel and Air Mixing

A variety of techniques to control fuel and air mixing in utility and industrial boilers is available. They include:

- low excess air
- overfire air
- low-NOx burners
- air staging

Low excess air (LEA). This simply involves reducing the amount of excess air supplied to the boiler to aid combustion. Incomplete combustion and increased smoke can occur if the level of excess air is too low.

- NOx reduction potential 5-15%
- SO_2 reduction potential 0
- CO_2 reduction potential 0
- Status: Demonstrated full scale, common use
- Cost: No added cost on a new boiler.

Overfire air. This involves redirection of some combustion air to a region above the top row of burners. Again, incomplete combustion and increased smoke may occur.

- NOx reduction potential 30%
- SO_2 reduction potential 0
- CO_2 reduction potential 0
- Status: Demonstrated full scale, common use
- Cost: No added cost on a new boiler.

Low-NOx burners (LNB). These burners are specially designed to control air and fuel injection to the boiler such that the initial mixing of the coal and combustion air is limited thereby creating a lower temperature combustion zone and less NOx formation. They operate as well as conventional burners on new boilers where the boiler has been designed for the modified combustion regime they create. Some problems have been experienced with carbon carry over (incomplete combustion) in retrofits.

- NOx reduction potential 25-50%
- SO_2 reduction potential 0
- CO_2 reduction potential 0
- Status: Demonstrated full scale on both targential - and wall-fired boilers
- Cost: No added cost on a new boiler.
  Retrofit Cost $5-8/kw

Air Staging. With advanced air staging up to 50 percent of the combustion air is redirected above the low-NOx burners (typical overfire air concepts redirect less than 25 percent of the combustion air).

- NOx reduction potential 50-80%
- SO_2 reduction potential 0
- CO_2 reduction potential 0
- Status: Commercially available
- Cost: Unknown.

b) Fuel Reburning

This involves diverting about 10 percent of the primary fuel (or the use of a secondary fuel, typically natural gas) into a region above the burners so that a fuel rich zone is created. In this secondary combustion zone, local chemical reducing conditions convert some of the NO to molecular nitrogen thereby reducing NOx emissions. Use of a low fuel nitrogen secondary fuel (natural gas) tends to be more effective than reburning a coal or oil primary fuel.

- NOx reduction potential 50%
  60-80% when combined with LNB
- SO_2 reduction potential 0
- CO_2 reduction potential Modest reduction

- Status: Demonstrated full scale in Japan
  Pilot scale testing in N. Am.
- Cost: Unknown, dependent on differential fuel costs if a secondary fuel used.

c) Slagging Combustors

In these devices the coal is partially gasified in staged combustion chambers outside the boiler and then the hot gases are injected into the boiler to complete the combustion process. The combustion chamber replaces the normal burners. Particulate emissions are controlled by converting ash into molten slag and removing it before entering the boiler. NOx formation is suppressed by staged combustion to control temperatures in the combustion chamber and SO_2 is reduced by the injection of alkali compounds.

- NOx reduction potential 70-80%
- SO_2 reduction potential 70-90%
- CO_2 reduction potential 0
- Status: Pilot scale
- Cost: Unknown.

d) Advanced Sorbent Injection (SI) Processes

In-furnace sorbent injection involves the injection of dry calcium - based sorbents such as limestone, hydrated lime or dolomite directly into the furnace. The primary purpose of SI systems is usually to remove sulphur by means of a sulphation reaction between the sorbent and the sulphur liberated from the fuel in combustion. However, selected sorbent types, such as UREA (N_2H_4CO), have demonstrated significant NOx reduction potential as well. Sorbent injection processes can result in increased particulate collection and waste disposal problems.

- NOx reduction potential 35-85%
- SO_2 reduction potential 55-70%
- CO_2 reduction potential Negative
- Status: Demonstration stage for advanced processes
- Cost: Low additional cost for NOx if primary purpose is SO_2 removal.

e) Selective Catalytic Reduction (SCR)

SCR systems involve use of a catalyst and the injection of ammonia in a scrubber like device installed on the flue gas discharge system of a boiler. The system converts NO to elemental nitrogen and water. It is considered best available technology for NOx control in Germany, Austria and Japan.

- NOx reduction potential 70-90%
- SO_2 reduction potential 0
- CO_2 reduction potential 0
- Status: Demonstrated full-scale on utility and industrial boilers.
- Cost: New 10-15 mills/kwh
  Retrofit 12-18 mills/kwh

f) Copper Oxide Reduction

Copper oxide (CuO) is used dry in a fixed bed or fluidized bed reactor. The CuO reacts with SO^2 in the flue gas to form copper sulphate. Ammonia is added as with SCR and the copper sulphate becomes a catalyst for the selective reduction of NO to molecular nitrogen.

- NOx reduction potential 90%
- SO_2 reduction potential 90%
- CO_2 reduction potential 0

- Status: Pilot scale
- Cost: Unknown.

g) NOXSO Process

Sodium oxide is used on alimina in a fluidized bed absorber. SO_2 is captured in the form of sodium sulphate and NO in the form of sodium nitrate. These products are then regenerated with hydrogen sulphide to yield sodium oxide (which is recycled back to the absorber), elemental sulphur and molecular nitrogen.

- NOx reduction potential 90%
- SO_2 reduction potential 90%
- CO_2 reduction potential 0
- Status: Pilot scale
- Cost: Unknown.

h) SULF-X Process

An iron sulphide slurry is used in a fairly complex absorber process to regenerate SO_2 and NOx.

- NOx reduction potential 70-90%
- SO_2 reduction potential 90%
- CO_2 reduction potential 0
- Status: Full scale application
- Cost: Unknown

i) Atmospheric Fluidized Bed Combustion (AFBC)

In Fluidized Bed Combustion fuel is burned in a bed of granular material which is fluidized by the injection of air from below the bed.

There are two major types of atmospheric fluidized bed combustion (AFBC) systems: bubbling-bed and circulating-bed. They differ in the location of their heat absorption surfaces, feedstock particle size, and throughput velocities.

In bubbling bed AFBC, a relatively dense bed of solids is maintained at the top of the furnace by firing relatively large-size coal and limestone particles and operating at relatively low velocities. Approximately 90 percent of the combustion and sulphur capture takes place in the bed of dense solids. Lower combustion temperatures (850°C) than in pulverized coal fired boilers result in lower formation of "thermal" NOx.

The circulating fluidized bed design goes a step further. This design actually induces solids to escape the combustion area and recycles them back into the combustion chamber. Air injected from below the bed (i.e., underbed feed) at high velocity fluidizes fuel and sorbent particles and lifts the burning mass the full height of the boiler, with no distinct boundary of the bed visible. After releasing heat to the water-walls in the boiler and the superheater, the particulate-laden combustion gases flow into hot cyclones. Particles removed by the cyclones are then recirculated to the original combustion chamber, where they mix with fresh fuel and limestone. The flue gas flows through convective heat-transfer sections, an air heater, then through fabric filters and out the stack. The long furnace retention time for the fuel and limestone and their continuous circulation allows for complete fuel combustion and the removal of sulphur dioxide.

The circulating fluidized bed boilers tend to have higher combustion efficiencies than the bubbling bed design. Other advantages over the bubbling bed design are that circulating

systems have less demanding fuel-feeding techniques, require less limestone to capture sulphur dioxide, and can be more easily adapted for combustion techniques to control emission of nitrogen oxides.

- NOx reduction potential 50-80%
- SO_2 reduction potential 90-95%
- CO_2 reduction potential -1%
- Status: Demonstrated Industrial scale
- Cost: No additional cost over a pulverized coal fired boiler with FGD.

j) Pressurized Fluidized Bed Combustion (PFBC)

In PFBC systems, as with AFBC, combustion takes place in a bed of small particles of solid fuel and a sorbent fluidized by a stream of air and combustion gases, but under pressure in the range of 8-12 atmospheres. In the three basic concepts of PFBC design, the relative amounts of electricity generated varies between conventional steam turbine generation and electricity generated in gas turbines driven by the pressurized combustion gases.

Advantages of PFBC over AFBC include higher overall thermal efficiency (40%), and smaller size, because of a higher operating pressure, and improved capability for modular fabrication and construction.

- NOx reduction potential 80-90%
- SO_2 reduction potential 90-95%
- CO_2 reduction potential 10
- Status: Demonstrated at small scale (25 MW), larger units under construction
- Cost: $1500/kw new plant
  $800-900/kw repowering

k) Integrated Gasification Combined Cycle (IGCC)

IGCC systems integrate and synchronize the coal gasification and electricity generation processes. Generally hot gases from a gasifier are used to drive a gas turbine; exit gases from the turbine are directed to a steam generator where steam is produced to drive a steam turbine. The combination of gas turbine and steam turbine electricity generation constitutes the combined cycle portion of the plant.

- NOx reduction potential 90-95%
- SO_2 reduction potential 99%
- CO_2 reduction potential 20% theor.
- Status: 1st generation small utility size demonstrated.
- Cost: 70-75 mills/kwh

2. Reciprocating Compressor Engines

Best practicable technology for reciprocating compressor engines consists of a combination of operational adjustments and hardware additions. Operational adjustments include changing the air-to-fuel ratio, retarding ignition timing, and de-rating the engine. Hardware additions include exhaust gas recirculation, redesigned combustion chambers, and reduced manifold air temperature.

Best available technology for reciprocating engines is the installation of catalytic exhaust gas treatment systems which reduce NOx to N_2. Also, gas fired reciprocating compressors could be replaced over time with electrically driven compressors. This would shift some of the emission burden from the natural gas industry to the electric power industry.

- NOx reduction potential
  - LN gas-fired compressors 40-60%
  - Catalytic exhaust gas treatment 70-90%
  - electrically driven compressors 100%
- SO_2 reduction potential 0
- CO_2 reduction potential 0
- Status: Available, demonstrated
- Cost: $3,000-4,000/tonne NOx removed

TABLE 2.3.1
SUMMARY - NOx CONTROL TECHNOLOGIES

	EMISSION REDUCTION POTENTIAL (%) NOx	VOC	SO2	CO2
MOBILE SOURCES				
(a) Light Duty Gasoline Vehicles (LDGV) - Improved catalysts & air-fuel mixture control, exhausts gas recirc.	90	90	0	0/-3
(b) Heavy Duty Diesel Vehicles (HDDV) - Turbocharging, aftercooling, improved injection, exhaust gas recirc. etc.	50	0	0	0/-4
(c) Off-Road Diesel - Same as (b)	45-55	38	0	0/-4
(d) Diesel Locomotives - Same as (b)	55-63	52-71	0	0/-4
STATIONARY SOURCES				
(a) Utility & Ind. Boilers				
Control of Combustion Process:				
- Low excess air	5-15	0	0	0
- Overfire air	30	0	0	0
- Low-NOx Burners	20-50	0	0	0
- Air Staging	50-80	0	0	0
- Fuel reburning	50	0	0	0
- Slagging combustors	70-80	0	70-90	0
Sorbent Injection (SI) processes:				
- Selected sorbent for NOx reduction	35-85	0	55-70	-1
- SI + fuel reburning	60-80	0	55-70	-1
Alternative Combustion techniques:				
- Atmospheric Fluid. Bed Comb. (AFCB)	70-90	0	90	-1
- Pressurized Fluid. Bed Comb. (PFBC)	80-90	0	95	10
- Int. Gasif. Combined Cycle (IGCC)	90-95	0	99	20
Flue Gas Cleanup Technologies:				
- Selective catalytic reduction (SCR)	70-90	0	0	0/-3
- Selective non-catalytic reduction	50-60	0	0	
- Copper - oxide process	90	0	90	
- NOXSO process	90	0	90	
- SULF-X process	70-90	0	90	
(b) Gas-Fired Recip. Compressors				
- Operational, ignition and design changes	40-60	0	0	
- Catalytic exhaust gas treatment	70-90	0	0	

TABLE 2.3.2
SUMMARY - SELECTED NOx CONTROL OPTIONS, EMISSION REDUCTION POTENTIAL AND COSTS

		NOx REDUCTION POTENTIAL				COST (1987$)	
CONTROL/TECHNOLOGY[1]	APPLICATION ASSUMPTION	CURRENT NOx CONTROL %	FROM NO CONTROL %	2005 ADD. ASSUMED[2] %	EST 2005 ADD. NATIONAL (KT/YR)	UNIT	2005 ANNUAL NATIONAL ($ X 10^6/YR)
A. Mobile Sources							
(1) LDGV - California Stds	Effective 1997	40	90	25	96	$90/VEH.	90
(2) HDV - 5 g/BHP-hr	Effective 1994	20	50	0	0		
(3) LDGV Inspection/Maintenance	Effective 1995	0	5	5	26	$15/VEH/YR	128+
(4) LN Off-road Diesel Engines	Effective 1996	0	45-55	18	56	$600-2000/T	34-112
(5) LN Diesel Locomotives	Effective 1997	0	55-63	50	88	$1100/T	97
B. Stationary Sources							
(6) LN New Recip. Engines	Effective 1990	0	40-60	45	14	$3000-4000/T	42-56
(7) LNB New Ind. Boilers	Effective 1995	0	20-50	25	7	0	0
(8) SCR New Ind. Boilers	Effective 1995	0	70-90	80	24	$5000-7500/T	120-180
(9) LNB Retrofit - Ind. Boilers	Application Pre-1995	0	20-50	25	38	$200-400/T	8-15
(10) SCR Retrofit - Ind. Boilers	Application Pre-1995	0	70-90	80	90	$8000-12000/T	720-1080
(11) SCR New Power Plants	Effective 1995	0	70-90	80	56	10-15 Mills/Kwh	280-420
(12) LNB Retrofit - Power Plants	Application Pre-1987	5	20-50	25	39	$200-400/T	8-16
(13) SCR Retrofit - Power Plants	Application Pre-1995	0	70-90	80	153	12-18 Mills/Kwh	1240-1860

TOTAL[3]							2760-4150

1 LDV = Light Duty Gasoline Vehicle
HDV = Heavy Duty Vehicle
LN = Low-NOx
LNB = Low-NOx Burner
SCR = Selective Catalytic Reduction

2 Estimated potential reduction is from "current control" level

3 Total is sum of rows 1, 2, 3, 4, 5, 6, 8, 10, 11, 13

TABLE 2.3.3

NOx CONTROL TECHNOLOGIES - REDUCTION POTENTIAL BY PROVINCE (KT/YR - YEAR 2005)

	MOBILE SOURCES					STATIONARY SOURCES								
	(1) NEW LDGV	(2) NEW HDV	(3) LDGV MAINT.	(4) OFFROAD DIESEL	(5) DIESEL LOCOMOTIVES	(6) LN NEW RECIP	(7) LNB NEW IND	(8) SCR NEW IND	(9) LN RETRO IND	(10) SCR RETRO IND	(11) SCR NEW POWER	(12) LNB RETRO POWER	(13) SCR RETRO POWER	TOTAL CANADA
B.C.	13	0	4	13	11	5	2	5	7	17	0	0	0	68
Alta.	11	0	3	9	24	0	1	1	4	11	38	15	47	143
Sask.	4	0	2	3	6	9	0	1	1	3	9	6	18	54
Man.	5	0	1	2	12	0	0	1	1	2	0	0	0	23
Ont.	35	0	9	10	20	0	3	10	15	35	0	9	54	172
Que.	22	0	4	9	9	0	1	3	7	15	0	0	0	62
N.B.	2	0	1	2	2	0	0	1	1	3	9	5	17	37
N.S.	3	0	1	4	4	0	0	1	1	2	0	3	13	28
Nfld.	1	0	5	2	0	0	0	1	1	2	0	1	4	12
P.E.I.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Y/NWT	0	0	0	2	0	0	0	0	0	0	0	0	0	2
	96	0	26	56	88	14	7	24	38	90	56	39	153	601

* Totals for Canada are sum of columns 1, 2, 3, 4, 5, 6, 8, 10, 11, 13

APPENDIX A

REFERENCE

NATIONAL Acid Precipitation Assessment Programs (NAPAP), interim Assessment, the Causes and Effects of Acidic Deposition, Volume II: Emissions and Controls.

Radian Corporation, Feasibility and Cost-Effectiveness of Controlling Emissions from Diesel Engines in Rail, Marine, Construction, Farm, and Other Mobile Off-Highway Equipment, prepared for U.S. EPA, February, 1988.

Damon, J.E. et al., Updated Technical and Economic Review of Selective Catalytic NOx Reduction Systems, New Orleans NOx Symposium, March, 1987.

REPORT NO. 3.1

VOC EMISSION INVENTORY - 1985

Prepared for:

Federal-Provincial Advisory Committee
on Air Quality

Conservation and Protection
Environment Canada

July 1989

3.1 VOC EMISSION INVENTORY - 1985

The objective of this section of the VOC information report is to provide an estimate of the national and provincial emissions of volatile organic compounds (VOC). The estimates presented in the following tables and figures represent calculated emission estimates and do not represent the results of a program for the measurement of actual emissions. They are useful in identifying the sources of VOC, their distribution and their relative magnitudes.

The term volatile organic compounds (VOC) as used here is meant to cover all gaseous emissions of hydrocarbon compounds as a class, excluding methane. The tables and figures in this section have consequently been titled Non-methane Hydrocarbons.

With the exception of a limited amount of data on industrial processes submitted by the provinces of British Columbia and Ontario, the VOC inventory was compiled from federally developed emission data. (Additional data were supplied by the province of Ontario but, due to lack of time for review, were not used in compiling the inventory). A short description of the methodology used follows.

3.1.1 Methodology

The emissions of volatile organic compounds were calculated, in most part, using emission factors for total hydrocarbons. The methane fraction was removed to obtain VOC emission estimates using EPA developed hydrocarbon chemical profiles. These profiles are being refined and additional detail will be incorporated into this methodology in time.

Industrial Processes: Table 3.1.2

As mentioned above, only limited data were available from the provinces on emissions of volatile organic compounds from industrial processes. Consequently, background information on specific plants supplied by the

provinces as part of the NO_x data were combined with the latest emission factors reported in the literature to estimate emissions of volatile organic compounds.

The petroleum refining and petrochemicals sectors were dealt with differently. For petroleum refineries, detailed emission data by refinery including process emissions, emissions from storage tanks and from some types of fugitive sources were taken from a Petroleum Association for the Conservation of the Environment (PACE) report describing the industry in 1983. To reflect 1985 emissions, the emissions were prorated using 1985 refinery crude oil throughput figures. A correction factor was also applied to estimate those fugitive emissions not covered in the PACE report. For Ontario and British Columbia, the provincial estimates supplied by the respective Ministries were used.

A study was conducted by Environment Canada to estimate the emissions of volatile organic compounds from the petrochemical sector. The inventory was prepared using data from publicly available information sources and includes process emissions, fugitive emissions and emissions from storage of feed and product materials. The quantities of VOC emitted from sources at each chemical plant were calculated using the most recent emission factors from the U.S. EPA and data on plant production. The main source of production data for the chemical plants was Corpus Product Profiles published by Corpus Information Services.

It is important to note that the emissions estimates developed did not take into account the control practices currently in place in the petrochemical industry and hence, are more reflective of uncontrolled operations. A working group has been established with the Canadian Chemical Producers Association (CCPA) to refine the estimates of the inventory through a questionnaire survey of the major chemical producers. The results will be available in the calendar year 1989.

<u>Fuel Combustion - Stationary Sources:</u> Table 3.1.3

This category includes the emissions due to the combustion of fossil fuels in thermal power plants, in industrial sectors and in commercial and residential sectors. The emissions from power plants were calculated by using background data provided by the provinces or obtained from provincial power commissions and emission factors by fuel type. The emissions from industrial, commercial and residential fuel combustion were also estimated by Environment Canada from fuel consumption statistics compiled by Statistics Canada and from published emission factors available by fuel type.

<u>Transportation:</u> Table 3.1.4

The transportation category includes the emissions from the combustion of fuel in all forms of mobile equipment. This includes emissions from motor vehicles, from other forms of mass transport such as rail and marine and from the industrial or commercial use of mobile equipment such as construction equipment and agricultural machinery.

The emissions from gasoline and diesel-powered road motor vehicles were estimated by Environment Canada and were based on vehicle population figures, vehicle-miles travelled and emission factors. The emission factors were based on the Canadian version of MOBILE 3, a transportation model developed by the U.S. EPA and are national averages representative of the vehicle fleet, by vehicle type. The figures used for vehicle-miles travelled are also national averages and were derived from studies done by Transport Canada. Provincial vehicle population figures were taken from statistics published by Statistics Canada.

Since these estimates are based on data and model parameters which reflect, for the most part, national averages, provincial emission estimates can be refined by incorporating into MOBILE 3 parameters more representative of local conditions.

It is important to note that EPA is developing and will release shortly an upgraded version of MOBILE 3 called MOBILE 4. This newer version will greatly improve the capability to estimate the emissions of volatile organic compounds from motor vehicles. The current model has recently been found to seriously underestimate these emissions, particularly those defined as evaporative running losses.

The emissions from the other mobile sources considered under the Transportation Category were generally derived using fuel consumption statistics, as reported by Statistics Canada, and emission factors. It should be noted that the emission factors for a number of these sources have undergone revisions and are different from those reported previously in the literature and which were used in other inventory estimates. This is particularly the case for emission factors applicable to:

- rail transport;
- industrial diesel equipment;
- gasoline and diesel farm machinery.

Incineration and Miscellaneous Sources: Table 3.1.5

The emissions from these two categories were also calculated by Environment Canada. Emissions from the incineration of solid waste were based on the amount of municipal refuse and wood waste burned and on average emission factors. The emissions from slash burning were based on the number of acres of slash burned and emission factors reported in the literature.

The emissions from fuel marketing were estimated using net fuel sales as reported by Statistics Canada and EPA emission factors for loading/unloading of fuel, for storage of fuel (except at refineries) and during vehicle refueling at service stations.

The emissions from the application of surface coatings, dry cleaning establishments and general solvent use were estimated using the

quantity of solvents used as reported by Statistics Canada. With the exception of the application of surface coatings in industrial and commercial establishments, where some recovery of solvents occurs, it was assumed that all of the quantities of solvents used were emitted to the atmosphere.

3.1.2 Reactivity of VOCs

The importance of VOCs in ozone formation depends on their reactivity. Best estimates of the distribution of Canadian VOC emissions by compound classes are as follows:

° alkanes (moderately reactive) - 62 per cent;
° alkenes (highly reactive) - 16 per cent;
° aromatics (moderately reactive) - 19 per cent;
° aldehydes and ketones (highly reactive) - 3 per cent.

The distribution is relatively consistent across most emission sectors, with the exception of dry cleaning, where alkanes are about 10 per cent and alkenes about 90 per cent of emissions respectively.

Concentrations of VOCs in the ambient air in urban areas show a compound class distribution pattern similar to that of emissions.

3.1.3 Results

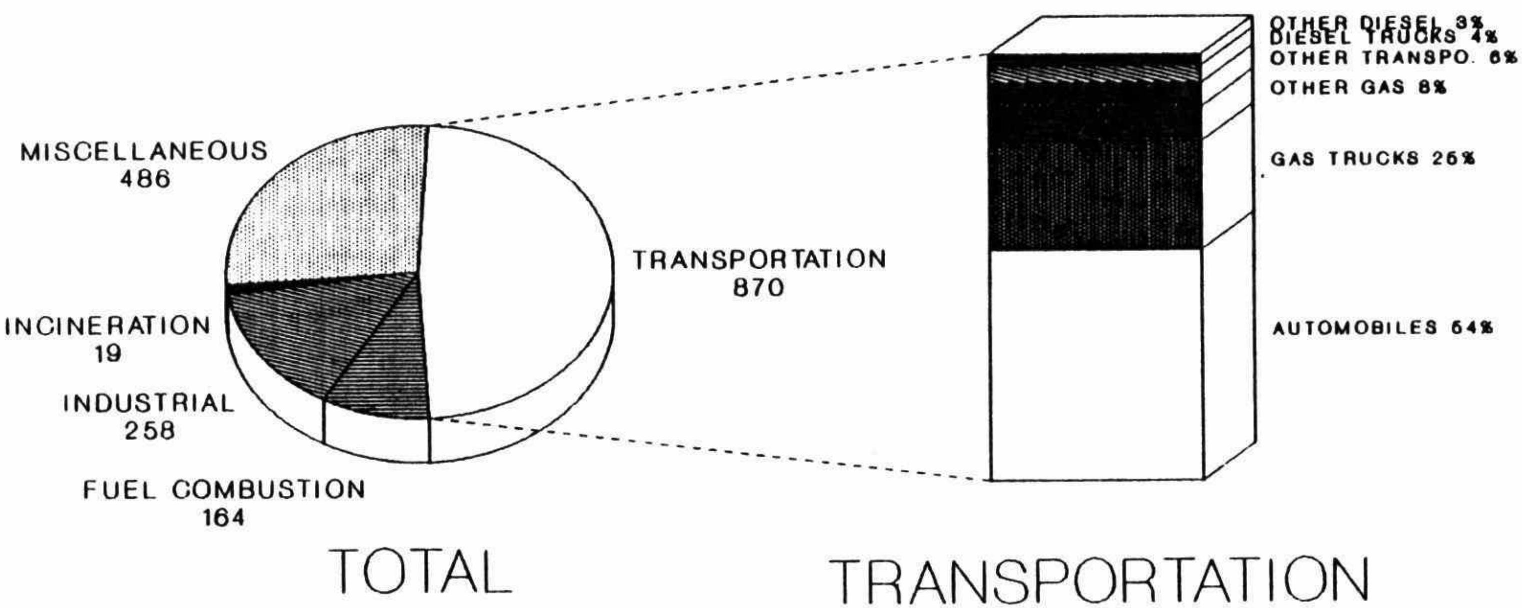
Nationally, the emissions of volatile organic compounds amount to 1.8 million tonnes. As for the NO_x inventory, the transportation category is the largest contributor to the national total, accounting for about 870 kilotonnes or about one half of the national emission total of volatile organic compounds. The miscellaneous category, including emissions from solvent use and fuel marketing, contribute another 486 kilotonnes or 27% while industrial processes add another 258 kilotonnes or 14%.

The transportation sector is also the major emission source in each of the provinces, the greatest contribution coming from gasoline powered motor vehicles.

The results of the VOC inventory nationally and provincially by category and sector are presented in Table 3.1.1 through 3.1.5 and in Figure 3.1.1.

FIGURE 3.1.1

NON-METHANE HYDROCARBON EMISSIONS 1985
NATIONAL



(KILOTONNES)

TABLE 3.1.1
SUMMARY OF PROVINCIAL NON - METHANE HYDROCARBON EMISSIONS - 1985
BY MAJOR CATEGORY

Emissions (tonnes)

CATEGORY	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
Industrial	49	5	4,426	2,842	50,727	114,172	1,599	4,196	63,256	16,818	193	0	258,283
Fuel Combustion	8,954	4,522	5,057	5,402	40,692	36,578	2,644	3,010	8,506	47,132	1,570	0	164,068
Transportation	17,815	4,148	29,988	22,782	144,624	298,939	47,029	56,806	115,420	128,542	2,650	1,471	870,215
Incineration	32	12	139	301	7,587	2,044	56	157	692	8,349	1	0	19,370
Miscellaneous	8,649	2,349	14,064	14,735	115,560	169,600	16,273	15,753	39,818	88,163	664	403	486,032
Total	35,499	11,037	53,674	46,062	359,191	621,332	67,601	79,922	227,691	289,005	5,079	1,874	1,797,968

TABLE 3.1.2
PROVINCIAL EMISSIONS OF NON - METHANE HYDROCARBONS
INDUSTRIAL PROCESSES CATEGORY - 1985

Emissions (tonnes)

SECTOR	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
Crude Oil	0	0	656	457	680	23	138	1,948	10,533	392	193	0	15,020
Refineries	0	0	3,194	1,269	7,058	15,414	0	1,669	5,302	6,258	0	0	40,164
Gas Plants	0	0	0	0	0	0	0	0	0	0	0	0	0
Coal Prod.	0	0	0	0	0	0	0	0	0	0	0	0	0
Petrochemicals	0	0	12	0	22,196	39,600	0	0	44,391	1,594	0	0	107,793
Plastics	31	0	320	474	12,519	28,766	1,155	200	2,547	2,607	0	0	48,619
Kraft Pulping	0	0	123	564	1,563	6,200	179	127	219	5,540	0	0	14,515
Other	18	5	122	78	6,711	24,169	127	252	263	427	0	0	32,172
TOTAL	49	5	4,426	2,842	50,727	114,172	1,599	4,196	63,256	16,818	193	0	258,283

TABLE 3.1.3
PROVINCIAL EMISSIONS OF NON - METHANE HYDROCARBONS
STATIONARY FUEL COMBUSTION CAREGORY - 1985

Emissions (tonnes)

SECTOR	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
INDUSTRIAL													
Refineries	0	0	3	2	20	617	0	1	18	10	0	0	671
Gas Plants	0	0	0	0	0	0	0	0	5,065	1,236	0	0	6,301
Other Industrial	42	1	28	46	272	452	31	63	213	41,468	1	-	42,617
SUBTOTAL	42	1	31	48	292	1,069	31	64	5,296	42,714	1	0	49,589
Commercial	8	36	24	13	133	454	240	58	236	123	6	0	1,331
Residential	22	8	301	33	262	675	69	293	789	205	5	-	2,662
Fuelwood	8,705	4,476	4,615	5,255	39,905	33,931	1,932	2,340	1,542	3,837	1,328	-	107,866
POWER PLANTS													
Utilities	66	1	82	53	0	442	306	244	626	108	0	0	1,927
Other	111	0	5	0	101	7	66	11	17	146	230	0	692
SUBTOTAL	177	1	86	53	101	448	372	254	643	254	230	0	2,620
TOTAL	8,954	4,522	5,057	5,402	40,692	36,578	2,644	3,010	8,506	47,132	1,570	0	164,068

NOTE : Emission estimates for N.W.T. include Yukon.
Statistics for Yukon were not reported separately.

TABLE 3.1.4
PROVINCIAL EMISSIONS OF NON - METHANE HYDROCARBONS
TRANSPORTATION CATEGORY - 1985

Emissions (tonnes)

SECTOR	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
GASOLINE													
Automobiles	6,984	2,262	15,184	11,533	102,981	179,453	21,262	16,059	53,454	60,891	372	302	470,735
L-D Trucks	4,248	1,108	8,374	6,725	17,690	62,816	12,245	17,468	22,730	36,887	764	723	191,778
H-D Trucks	924	258	1,563	1,256	4,370	2,837	2,285	3,700	4,824	6,885	149	135	29,185
Motorcycles	95	20	175	110	982	1,546	172	76	432	743	10	6	4,366
SUBTOTAL	12,251	3,648	25,295	19,623	126,023	246,652	35,963	37,302	81,440	105,407	1,294	1,166	696,065
DIESEL													
L-D Trucks	22	6	44	35	93	717	64	92	120	193	4	4	1,393
H-D Trucks	717	191	1,650	1,136	3,709	10,938	2,093	3,121	4,329	6,229	143	151	34,408
Other *	467	80	786	394	2,720	4,183	1,308	3,382	5,645	3,878	528	-	23,370
SUBTOTAL	1,206	277	2,480	1,565	6,522	15,838	3,465	6,595	10,093	10,300	675	155	59,172
Total Road	13,457	3,925	27,775	21,188	132,544	262,491	39,428	43,898	91,534	115,707	1,969	1,321	755,236
Railroads *	67	8	319	20	1,323	2,374	1,346	755	2,645	1,315	11	-	10,183
Marine *	1,380	26	876	486	3,994	11,145	1,311	1,380	2,512	4,803	9	-	27,922
Aircraft	174	24	115	289	1,847	3,346	310	562	1,711	1,411	302	69	10,158
Off-road Gas	2,725	161	878	780	4,794	19,350	4,600	10,175	16,938	5,203	359	80	66,043
Tire Wear	12	4	25	19	122	234	35	37	80	103	1	1	673
TOTAL	17,815	4,148	29,988	22,782	144,624	298,939	47,029	56,806	115,420	128,542	2,650	1,471	870,215

* Emission estimates for Yukon are included under N.W.T.
Statistics for Yukon were not reported separately.

TABLE 3.1.5
PROVINCIAL EMISSIONS OF NON - METHANE HYDROCARBONS
INCINERATION AND MISCELLANEOUS CATEGORIES - 1985

Emissions (tonnes)

SECTOR	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.	MAN.	SASK.	ALTA.	B.C.	N.W.T.	YUKON	NATIONAL
INCINERATION :													
Wood Waste	24	10	124	287	2,380	1,226	37	140	647	8,297	0	0	13,170
Other	8	2	15	14	5,207	818	19	17	45	52	1	0	6,200
TOTAL	32	12	139	301	7,587	2,044	56	157	692	8,349	1	0	19,370
MISCELLANEOUS :													
Fuel Marketing	1,853	576	3,688	3,213	23,272	41,552	4,558	4,475	12,927	12,350	119	188	108,771
Structural Fires	83	62	225	197	1,252	2,119	581	252	707	746	18	20	6,262
Slash Burning *	1,435	238	1,967	4,515	20,245	500	982	1,725	5,135	43,960	106		80,809
SOLVENT USE													
Dry Cleaning	1,028	226	1,563	1,275	11,699	19,300	1,903	1,805	4,201	5,129	90	40	48,259
Surface Coatings	1,817	718	2,962	2,534	31,603	54,329	3,802	3,267	6,977	13,975	122	61	122,167
General Use	2,433	529	3,659	3,001	27,489	51,800	4,447	4,229	9,871	12,003	209	94	119,764
SUBTOTAL	5,278	1,473	8,184	6,810	70,791	125,429	10,152	9,301	21,049	31,107	421	195	290,190
TOTAL	8,649	2,349	14,064	14,735	115,560	169,600	16,273	15,753	39,818	88,163	664	403	486,032

* Emission estimates for Yukon are included under N.W.T.
Statistics for Yukon were not reported separately.

REPORT NO. 3.2

VOC EMISSION PROJECTIONS 1985-2005

Prepared for:

Federal-Provincial Advisory Committee
on Air Quality

Conservation and Protection
Environment Canada

July 1989

3.2 VOC EMISSIONS PROJECTIONS 1985-2005

Revised forecasts have been generated for Canada and the provinces/territories using 1985 emission estimates as the base year extending to the year 2005. Modifications have been made to energy demand forecasts based on new data prepared by the National Energy Board, as well as to growth by industry sector as generated by Informetrica.

The accompanying tables and graphs by province/territory and for Canada provide a clear picture of VOC emissions for all sectors. Sources contributing significantly to total emissions have been segregated from the category totals. Data are illustrated for 5 years, starting with the 1985 base year inventory.

The major assumptions in developing the forecasts are:

° status quo emission controls - Current vehicle standards are included.

° National Energy Board (NEB) estimates have been used for car and truck stock growth rates.

° NEB estimates of energy demand were used for fuel consumption for all energy related sectors by fuel type and by province/territory.

° Informetrica economic and population growth estimates were used for other sources (by sector and by province/territory).

A summary of the generic methodology used in developing the forecasts including data sources for the base year inventory is included in Appendix A.

Based on these changes, the current national projections show a 133 kilotonne or a 7% increase between 1985 and 2005. Sectors with significant increases are: petrochemical industry (92%), crude oil

production (89%), plastics fabrication (64%) and slash burning (60%). These and other sector increases are largely offset by a 35% decrease in emissions from the motor vehicle (cars and trucks) sector.

Generally, a decrease of VOC emissions between 1985 and 2005 in the transportation category of 26% is offset by the following increases: 24% for stationary source fuel combustion, 72% for industrial processes, and 26% for the incineration and miscellaneous category.

TABLE 3.2.1
VOC PROJECTIONS - CANADA
(Kilotonnes)

PROVINCE: Canada

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	471.0	387.9	296.7	263.0	264.1
Light-Duty Trucks					
Gas	191.9	182.2	149.3	130.6	123.4
Diesel	1.3	1.3	1.8	2.4	3.0
Heavy-Duty Trucks					
Gas	29.3	24.8	20.8	21.2	23.3
Diesel	34.3	37.2	39.9	47.4	57.9
Off-Road Gasoline	66.1	64.8	66.5	70.3	74.3
Other	76.9	83.4	87.9	91.9	98.0
Fuel Combustion					
Fuelwood	107.7	111.8	119.3	128.5	132.7
Residential/Commercial	3.7	3.5	3.5	3.5	3.5
Industrial	49.5	46.0	52.1	57.3	63.9
Industrial Processes					
Petrochemicals	107.8	114.4	134.4	165.2	206.8
Petroleum Refining	40.3	42.7	44.4	46.5	49.3
Plastics	48.6	52.1	58.9	68.3	79.8
Crude Oil	15.0	14.9	18.2	26.2	28.3
Other	46.7	51.2	62.1	71.1	81.1
Incineration/Miscellaneous					
Surface Coatings	122.2	135.4	145.9	155.6	165.3
Fuel Marketing	109.0	109.0	113.7	119.1	124.4
Dry Cleaning	54.0	56.4	58.0	59.1	59.8
Solvent Use	120.1	125.5	129.4	132.1	133.5
Slash Burning	80.6	89.8	101.7	113.6	129.0
Other	25.6	25.7	28.0	29.7	32.4
Power Generation	2.7	2.7	2.7	2.7	2.7
T O T A L	1804.3	1752.7	1735.2	1805.3	1936.5

TABLE 3.2.2
VOC PROJECTIONS - NEWFOUNDLAND
(Kilotonnes)

PROVINCE: Newfoundland

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	7.0	5.9	4.5	4.0	4.0
Light-Duty Trucks					
Gas	4.3	4.3	3.5	3.0	2.9
Diesel	< 0.1	< 0.1	< 0.1	0.1	0.1
Heavy-Duty Trucks					
Gas	0.9	0.6	0.5	0.5	0.6
Diesel	0.7	0.8	0.8	1.0	1.2
Off-Road Gasoline	2.7	2.9	3.1	3.5	3.8
Other	2.3	2.4	2.6	2.7	2.8
Fuel Combustion					
Fuelwood	8.7	8.7	9.1	9.4	9.8
Residential/Commercial	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Industrial	< 0.1	0.1	0.1	0.1	0.1
Industrial Processes					
Petrochemicals	-	-	-	-	-
Petroleum Refining	-	-	-	-	-
Plastics	< 0.1	< 0.1	< 0.1	< 0.1	0.1
Crude Oil	-	-	1.7	9.0	11.0
Other	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Incineration/Miscellaneous					
Surface Coatings	1.8	2.0	2.1	2.2	2.3
Fuel Marketing	1.9	1.9	2.0	2.0	2.1
Dry Cleaning	1.2	1.3	1.4	1.4	1.5
Solvent Use	2.4	2.6	2.7	2.9	3.0
Slash Burning	1.4	1.7	1.8	2.0	2.5
Other	0.1	0.1	0.1	0.1	0.1
Power Generation	0.2	0.2	0.2	0.2	0.2
T O T A L	35.6	35.5	36.2	44.1	48.0

TABLE 3.2.3
VOC PROJECTIONS - PRINCE EDWARD ISLAND
(Kilotonnes)

PROVINCE: Prince Edward Island

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	2.3	1.9	1.5	1.3	1.3
Light-Duty Trucks					
Gas	1.1	1.1	0.9	0.8	0.8
Diesel	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Heavy-Duty Trucks					
Gas	0.3	0.2	0.1	0.2	0.2
Diesel	0.2	0.2	0.2	0.3	0.3
Off-Road Gasoline	0.2	0.2	0.2	0.2	0.2
Other	0.1	0.2	0.2	0.2	0.2
Fuel Combustion					
Fuelwood	4.5	4.5	4.7	4.9	5.0
Residential/Commercial	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Industrial	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Industrial Processes					
Petrochemicals	-	-	-	-	-
Petroleum Refining	-	-	-	-	-
Plastics	-	-	-	-	-
Crude Oil	-	-	-	-	-
Other	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Incineration/Miscellaneous					
Surface Coatings	0.7	0.8	0.8	0.8	0.8
Fuel Marketing	0.6	0.6	0.6	0.6	0.7
Dry Cleaning	0.3	0.3	0.3	0.3	0.3
Solvent Use	0.5	0.6	0.6	0.7	0.6
Slash Burning	0.2	0.3	0.3	0.3	0.4
Other	0.1	0.1	0.1	0.1	0.1
Power Generation	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
T O T A L	11.1	11.0	10.5	10.7	10.9

TABLE 3.2.4.
VOC PROJECTIONS - NOVA SCOTIA
(Kilotonnes)

PROVINCE: Nova Scotia

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	15.2	12.8	9.8	8.7	8.7
Light-Duty Trucks					
Gas	8.4	8.4	6.9	6.0	5.7
Diesel	< 0.1	0.1	0.1	0.1	0.1
Heavy-Duty Trucks					
Gas	1.6	1.0	0.9	0.9	1.0
Diesel	1.7	1.8	1.9	2.2	2.7
Off-Road Gasoline	0.9	0.9	0.9	1.0	1.1
Other	2.3	2.7	2.9	3.1	3.4
Fuel Combustion					
Fuelwood	4.6	4.6	4.8	5.0	5.2
Residential/Commercial	0.3	0.3	0.3	0.3	0.3
Industrial	< 0.1	< 0.1	< 0.1	< 0.1	0.1
Industrial Processes					
Petrochemicals	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Petroleum Refining	3.2	3.5	3.6	3.8	4.1
Plastics	0.3	0.3	0.4	0.4	0.5
Crude Oil	0.7	0.5	0.2	0.1	0.1
Other	0.2	0.3	0.3	0.3	0.4
Incineration/Miscellaneous					
Surface Coatings	3.0	3.2	3.4	3.4	3.5
Fuel Marketing	3.7	3.8	3.9	4.0	4.2
Dry Cleaning	1.9	1.9	2.0	2.0	2.0
Solvent Use	3.7	3.8	3.9	4.0	4.0
Slash Burning	2.0	2.6	2.9	3.1	3.4
Other	0.4	0.4	0.4	0.4	0.5
Power Generation	0.1	0.1	0.1	0.1	0.1
T O T A L	54.2	53.0	49.6	48.9	51.0

TABLE 3.2.5
VOC PROJECTIONS - NEW BRUNSWICK
(Kilotonnes)

PROVINCE: New Brunswick

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	11.5	9.7	7.4	6.6	6.6
Light-Duty Trucks					
Gas	6.7	6.7	5.5	4.8	4.6
Diesel	< 0.1	< 0.1	0.1	0.1	0.1
Heavy-Duty Trucks					
Gas	1.3	0.8	0.7	0.7	0.8
Diesel	1.1	1.2	1.3	1.5	1.9
Off-Road Gasoline	0.8	0.8	0.8	0.9	0.9
Other	1.5	1.8	1.9	2.0	2.2
Fuel Combustion					
Fuelwood	5.3	5.2	5.5	5.7	5.9
Residential/Commercial	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Industrial	< 0.1	0.1	0.1	0.1	0.1
Industrial Processes					
Petrochemicals	-	-	-	-	-
Petroleum Refining	1.3	1.4	1.4	1.5	1.6
Plastics	0.5	0.5	0.6	0.6	0.7
Crude Oil	0.5	0.5	0.6	0.6	0.6
Other	0.6	0.7	0.8	0.9	1.0
Incineration/Miscellaneous					
Surface Coatings	2.5	2.8	2.9	2.9	2.9
Fuel Marketing	3.2	3.3	3.4	3.5	3.7
Dry Cleaning	1.5	1.6	1.7	1.7	1.7
Solvent Use	3.0	3.2	3.3	3.4	3.4
Slash Burning	4.5	6.3	7.0	7.6	8.1
Other	0.5	0.5	0.6	0.6	0.6
Power Generation	0.1	0.1	0.1	0.1	0.1
T O T A L	46.5	47.2	45.7	45.8	47.5

TABLE 3.2.6
VOC PROJECTIONS - QUEBEC
(Kilotonnes)

PROVINCE: Quebec

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	103.0	86.6	66.3	58.7	59.0
Light-Duty Trucks					
Gas	17.7	17.7	14.5	12.7	12.0
Diesel	0.1	0.1	0.2	0.2	0.3
Heavy-Duty Trucks					
Gas	4.4	2.9	2.4	2.5	2.7
Diesel	3.7	3.9	4.2	5.0	6.1
Off-Road Gasoline	4.8	5.0	5.5	5.9	6.4
Other	11.0	11.6	12.3	12.9	13.8
Fuel Combustion					
Fuelwood	39.9	46.7	50.0	51.5	53.5
Residential/Commercial	0.4	0.4	0.4	0.3	0.3
Industrial	0.3	0.3	0.4	0.4	0.4
Industrial Processes					
Petrochemicals	22.2	24.6	27.4	31.5	36.4
Petroleum Refining	7.1	7.5	7.7	8.0	8.4
Plastics	12.5	13.9	15.4	17.8	20.5
Crude Oil	0.7	0.6	0.6	0.6	0.6
Other	8.3	9.1	10.3	11.3	12.7
Incineration/Miscellaneous					
Surface Coatings	31.6	35.2	37.3	39.2	40.8
Fuel Marketing	23.3	23.3	24.9	26.3	27.2
Dry Cleaning	14.0	14.4	14.6	14.7	14.7
Solvent Use	27.6	28.3	28.8	28.9	28.9
Slash Burning	20.2	26.2	30.0	33.9	38.7
Other	8.8	9.2	9.7	10.0	10.5
Power Generation	0.1	0.1	0.1	0.1	0.1
T O T A L	361.7	367.6	363.0	372.4	394.0

TABLE 3.2.7
VOC PROJECTIONS - ONTARIO
(Kilotonnes)

PROVINCE: Ontario

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	179.5	142.8	109.2	96.8	97.2
Light-Duty Trucks					
Gas	62.8	53.2	43.6	38.1	36.0
Diesel	0.7	0.4	0.5	0.7	0.9
Heavy-Duty Trucks					
Gas	2.8	7.3	6.1	6.2	6.8
Diesel	10.9	12.3	13.1	15.6	19.1
Off-Road Gasoline	19.4	20.6	22.7	24.2	25.4
Other	22.7	24.7	25.3	25.6	26.5
Fuel Combustion					
Fuelwood	33.9	31.2	33.8	40.4	41.4
Residential/Commercial	1.1	1.1	1.2	1.2	1.3
Industrial	1.1	1.1	1.3	1.4	1.5
Industrial Processes					
Petrochemicals	39.6	42.0	47.2	54.4	62.7
Petroleum Refining	15.4	16.7	18.1	19.1	20.2
Plastics	28.8	30.5	34.3	39.5	45.6
Crude Oil	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Other	30.4	32.7	39.2	45.6	53.3
Incineration/Miscellaneous					
Surface Coatings	54.3	61.7	68.8	75.8	82.9
Fuel Marketing	41.6	44.3	48.8	51.9	54.6
Dry Cleaning	19.3	20.4	21.1	21.6	21.9
Solvent Use	51.8	54.7	56.7	58.0	58.8
Slash Burning	0.5	0.6	0.7	0.8	1.0
Other	4.2	4.6	5.1	5.5	6.0
Power Generation	0.4	0.4	0.4	0.4	0.4
T O T A L	621.2	603.3	598.2	622.8	663.5

TABLE 3.2.8
VOC PROJECTIONS - MANITOBA
(Kilotonnes)

PROVINCE: Manitoba

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	21.3	17.9	13.7	12.1	12.2
Light-Duty Trucks					
Gas	12.2	12.2	10.0	8.8	8.3
Diesel	0.1	0.1	0.1	0.2	0.2
Heavy-Duty Trucks					
Gas	2.3	1.5	1.3	1.3	1.4
Diesel	2.1	2.2	2.4	2.8	3.4
Off-Road Gasoline	4.6	4.3	4.3	4.4	4.7
Other	4.5	5.0	5.3	5.6	6.0
Fuel Combustion					
Fuelwood	1.9	1.5	1.5	1.4	1.3
Residential/Commercial	0.3	0.3	0.2	0.2	0.2
Industrial	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Industrial Processes					
Petrochemicals	-	-	-	-	-
Petroleum Refining	-	-	-	-	-
Plastics	1.2	1.2	1.4	1.6	1.8
Crude Oil	0.1	0.1	0.2	0.2	0.1
Other	0.3	0.3	0.4	0.4	0.4
Incineration/Miscellaneous					
Surface Coatings	3.8	4.1	4.2	4.2	4.2
Fuel Marketing	4.6	4.2	4.0	4.1	4.2
Dry Cleaning	2.3	2.4	2.4	2.4	2.4
Solvent Use	4.5	4.7	4.8	4.8	4.8
Slash Burning	1.0	1.4	1.5	1.8	2.0
Other	0.6	0.7	0.7	0.7	0.7
Power Generation	0.4	0.4	0.4	0.4	0.4
T O T A L	68.1	64.5	58.8	57.4	58.7

TABLE 3.2.9
VOC PROJECTIONS - SASKATCHEWAN
(Kilotonnes)

PROVINCE: Saskatchewan

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	16.1	13.5	10.3	9.2	9.2
Light-Duty Trucks					
Gas	17.5	17.5	14.3	12.5	11.8
Diesel	0.1	0.1	0.2	0.2	0.3
Heavy-Duty Trucks					
Gas	3.7	2.5	2.1	2.1	2.3
Diesel	3.1	3.3	3.5	4.2	5.1
Off-Road Gasoline	10.2	9.1	8.6	9.0	9.8
Other	6.3	6.1	6.4	6.9	7.4
Fuel Combustion					
Fuelwood	2.3	2.1	2.2	2.3	2.2
Residential/Commercial	0.3	0.2	0.2	0.2	0.2
Industrial	0.1	0.1	0.1	0.1	0.1
Industrial Processes					
Petrochemicals	-	-	-	-	-
Petroleum Refining	1.7	1.6	1.5	1.6	1.8
Plastics	0.2	0.2	0.3	0.3	0.4
Crude Oil	1.9	2.3	2.5	2.6	2.5
Other	0.4	0.4	0.5	0.6	0.7
Incineration/Miscellaneous					
Surface Coatings	3.3	3.5	3.5	3.5	3.5
Fuel Marketing	4.5	4.0	3.7	3.9	4.2
Dry Cleaning	2.2	2.3	2.4	2.5	2.6
Solvent Use	4.3	4.5	4.8	4.9	5.1
Slash Burning	1.7	2.8	3.2	3.6	4.1
Other	0.4	0.4	0.5	0.5	0.5
Power Generation	0.3	0.3	0.3	0.3	0.3
TOTAL	80.6	76.8	71.1	71.0	74.1

TABLE 3.2.10
VOC PROJECTIONS - ALBERTA
(Kilotonnes)

PROVINCE: Alberta

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	53.5	45.0	34.4	30.5	30.6
Light-Duty Trucks					
Gas	22.7	22.7	18.6	16.3	15.4
Diesel	0.1	0.2	0.2	0.3	0.4
Heavy-Duty Trucks					
Gas	4.8	3.2	2.7	2.7	3.0
Diesel	4.3	4.6	4.9	5.8	7.1
Off-Road Gasoline	16.9	15.4	14.8	15.4	15.9
Other	13.0	13.6	14.2	15.1	16.1
Fuel Combustion					
Fuelwood	1.5	1.5	1.6	1.7	1.7
Residential/Commercial	1.0	0.9	0.9	1.0	0.9
Industrial	5.3	5.1	5.7	5.9	5.8
Industrial Processes					
Petrochemicals	44.4	46.1	57.8	77.1	105.1
Petroleum Refining	5.3	5.5	5.7	6.0	6.3
Plastics	2.5	2.7	3.3	4.4	6.0
Crude Oil	10.5	10.0	11.2	11.5	11.2
Other	0.5	0.6	0.7	0.8	0.9
Incineration/Miscellaneous					
Surface Coatings	7.0	7.2	7.3	7.5	7.8
Fuel Marketing	12.9	11.7	11.1	11.5	11.8
Dry Cleaning	5.0	5.1	5.2	5.4	5.5
Solvent Use	9.9	10.0	10.3	10.6	10.8
Slash Burning	5.1	7.6	8.8	9.9	11.3
Other	1.4	1.5	1.6	1.6	1.8
Power Generation	0.6	0.6	0.6	0.6	0.6
T O T A L	228.2	220.8	221.6	242.6	276.0

TABLE 3.2.11
VOC PROJECTIONS - BRITISH COLUMBIA
(Kilotonnes)

PROVINCE: British Columbia

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	60.9	51.2	39.2	34.7	34.9
Light-Duty Trucks					
Gas	36.9	36.9	30.3	26.4	24.9
Diesel	0.2	0.3	0.4	0.5	0.6
Heavy-Duty Trucks					
Gas	6.9	4.6	3.8	3.9	4.3
Diesel	6.2	6.6	7.1	8.4	10.3
Off-Road Gasoline	5.2	5.2	5.2	5.4	5.7
Other	12.2	14.3	15.7	16.6	18.4
Fuel Combustion					
Fuelwood	3.8	4.3	4.5	4.6	5.0
Residential/Commercial	0.3	0.3	0.3	0.3	0.3
Industrial	42.7	39.2	44.4	49.3	55.8
Industrial Processes					
Petrochemicals	1.6	1.7	2.0	2.2	2.6
Petroleum Refining	6.3	6.5	6.4	6.5	6.9
Plastics	2.6	2.8	3.2	3.7	4.2
Crude Oil	0.4	0.4	0.5	0.5	0.5
Other	6.0	7.1	9.9	11.2	11.7
Incineration/Miscellaneous					
Surface Coatings	14.0	14.7	15.4	15.9	16.4
Fuel Marketing	12.4	11.6	11.0	11.0	11.4
Dry Cleaning	6.1	6.5	6.7	6.9	7.0
Solvent Use	12.1	12.8	13.2	13.5	13.7
Slash Burning	43.9	40.2	45.4	50.5	57.4
Other	9.1	8.2	9.2	10.2	11.5
Power Generation	0.3	0.3	0.3	0.3	0.3
T O T A L	290.1	275.7	274.1	282.5	303.8

TABLE 3.2.12
VOC PROJECTIONS - YUKON AND NORTHWEST TERRITORIES
(Kilotonnes)

PROVINCE: Yukon/Northwest Territories

SECTOR	1985	1990	1995	2000	2005
Transportation					
Cars	0.7	0.6	0.4	0.4	0.4
Light-Duty Trucks					
Gas	1.5	1.5	1.2	1.1	1.0
Diesel	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Heavy-Duty Trucks					
Gas	0.3	0.2	0.2	0.2	0.2
Diesel	0.3	0.3	0.3	0.4	0.5
Off-Road Gasoline	0.4	0.4	0.4	0.4	0.4
Other	1.0	1.0	1.1	1.2	1.2
Fuel Combustion					
Fuelwood	1.3	1.5	1.6	1.6	1.7
Residential/Commercial	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Industrial	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Industrial Processes					
Petrochemicals	-	-	-	-	-
Petroleum Refining	-	-	-	-	-
Plastics	-	-	-	-	-
Crude Oil	0.2	0.5	0.7	1.1	1.7
Other	-	-	-	-	-
Incineration/Miscellaneous					
Surface Coatings	0.2	0.2	0.2	0.2	0.2
Fuel Marketing	0.3	0.3	0.3	0.3	0.3
Dry Cleaning	0.2	0.2	0.2	0.2	0.2
Solvent Use	0.3	0.3	0.3	0.4	0.4
Slash Burning	0.1	0.1	0.1	0.1	0.1
Other	< 0.1	< 0.1	< 0.1	< 0.1	0.1
Power Generation	0.2	0.2	0.2	0.2	0.2
T O T A L	7.0	7.3	7.2	7.8	8.6

FIGURE 3.2.1

VOC EMISSIONS:1985-2005
CANADA

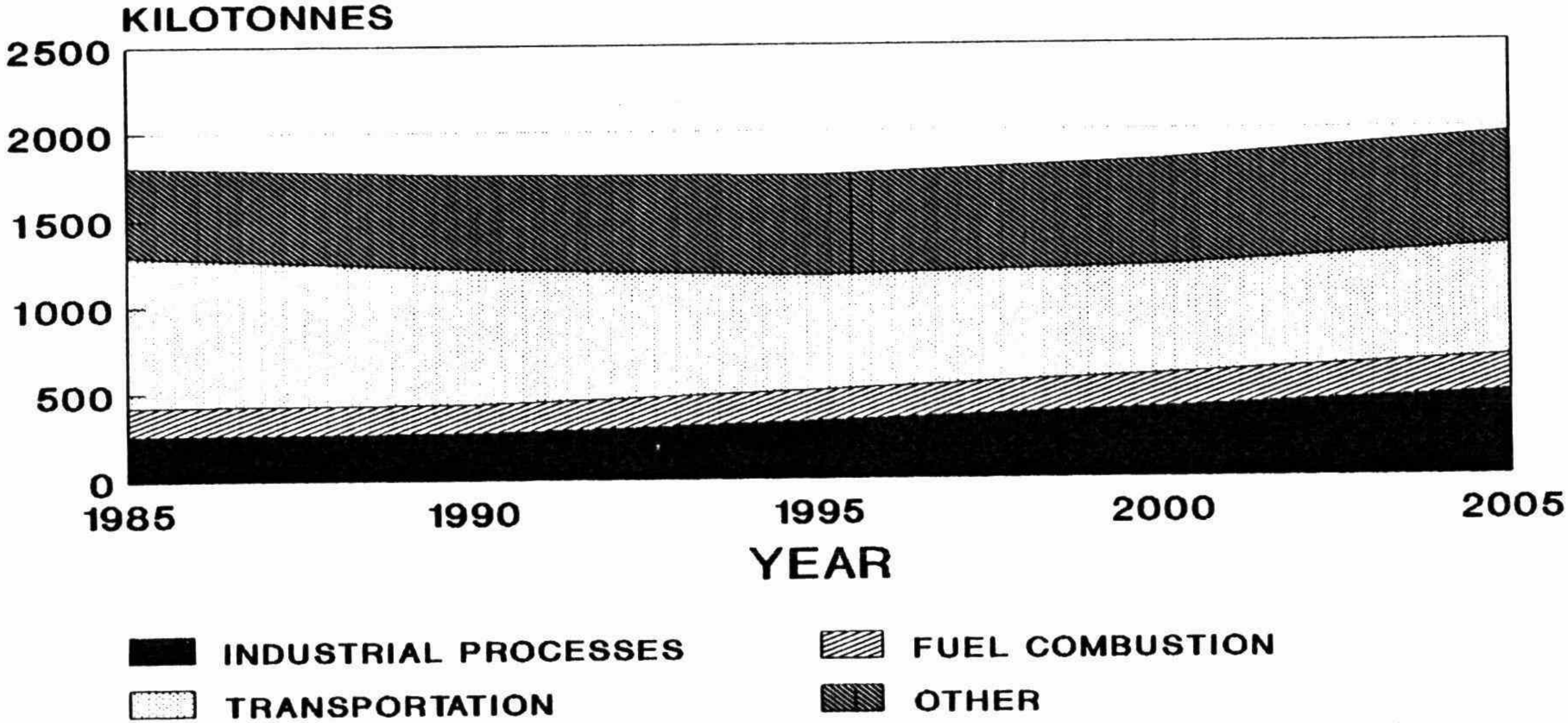


FIGURE 3.2.2

VOC EMISSIONS:1985-2005
NEWFOUNDLAND

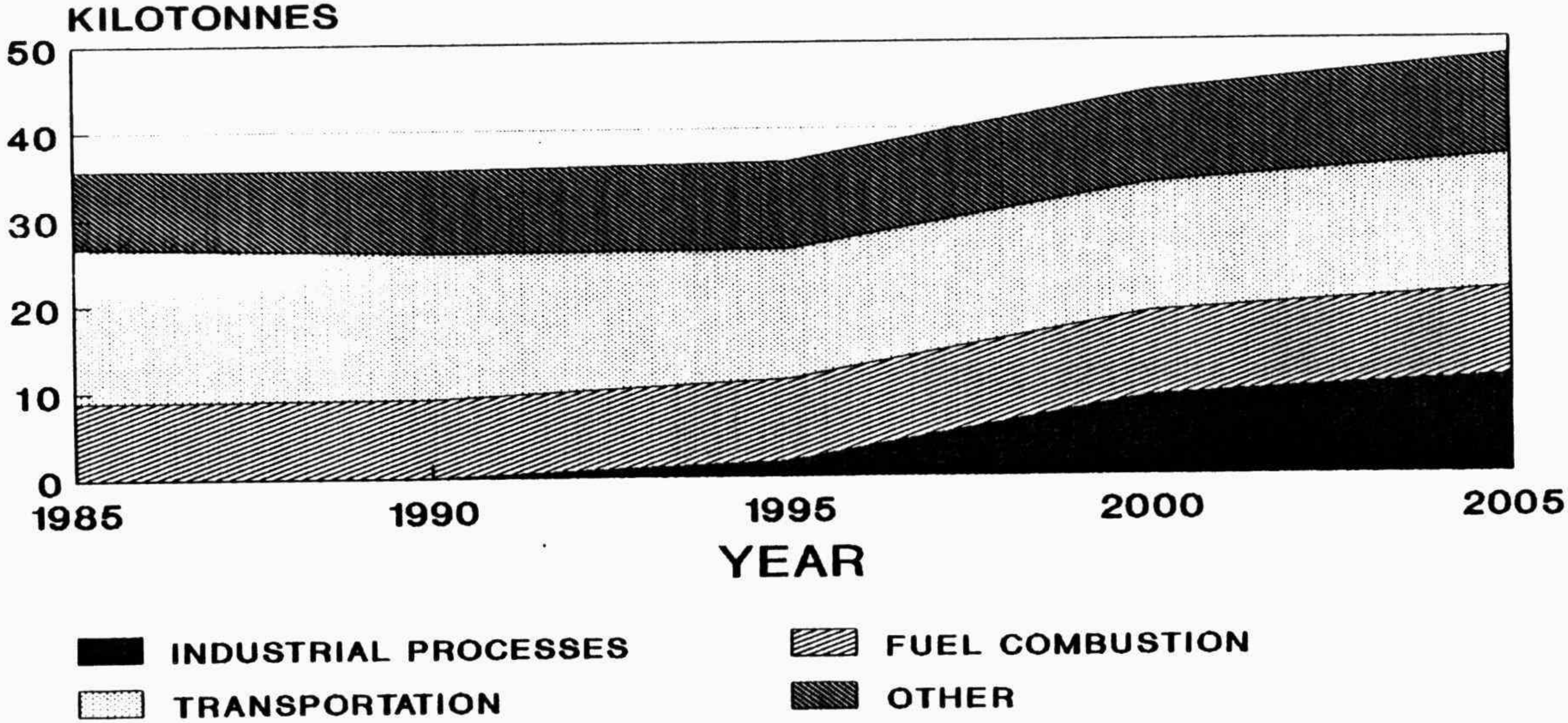


FIGURE 3.2.3

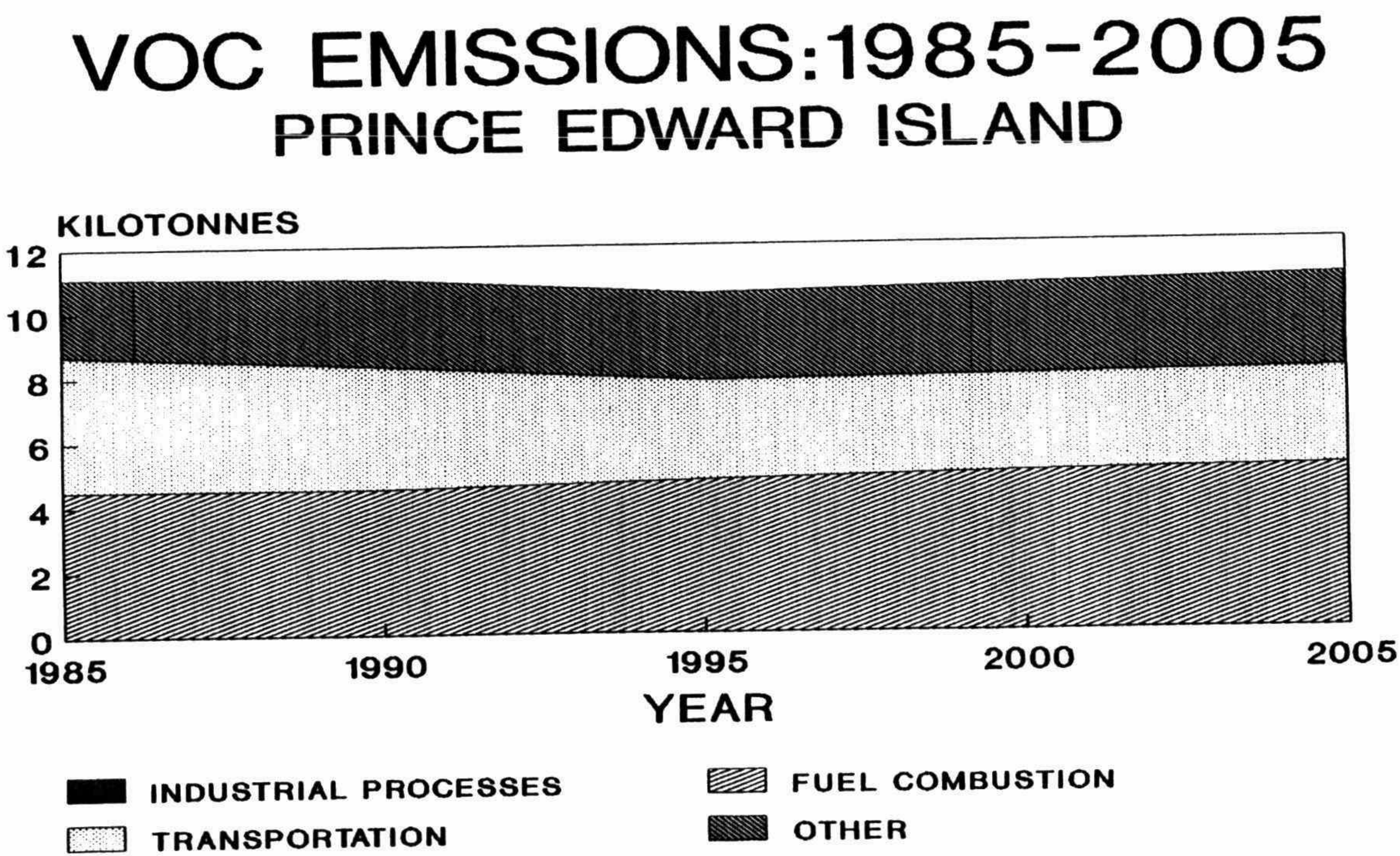

VOC EMISSIONS:1985-2005
PRINCE EDWARD ISLAND
KILOTONNES
12
10
8
6
4
2
0
1985
1990
1995
2000
2005
YEAR
INDUSTRIAL PROCESSES
TRANSPORTATION
FUEL COMBUSTION
OTHER

FIGURE 3.2.4

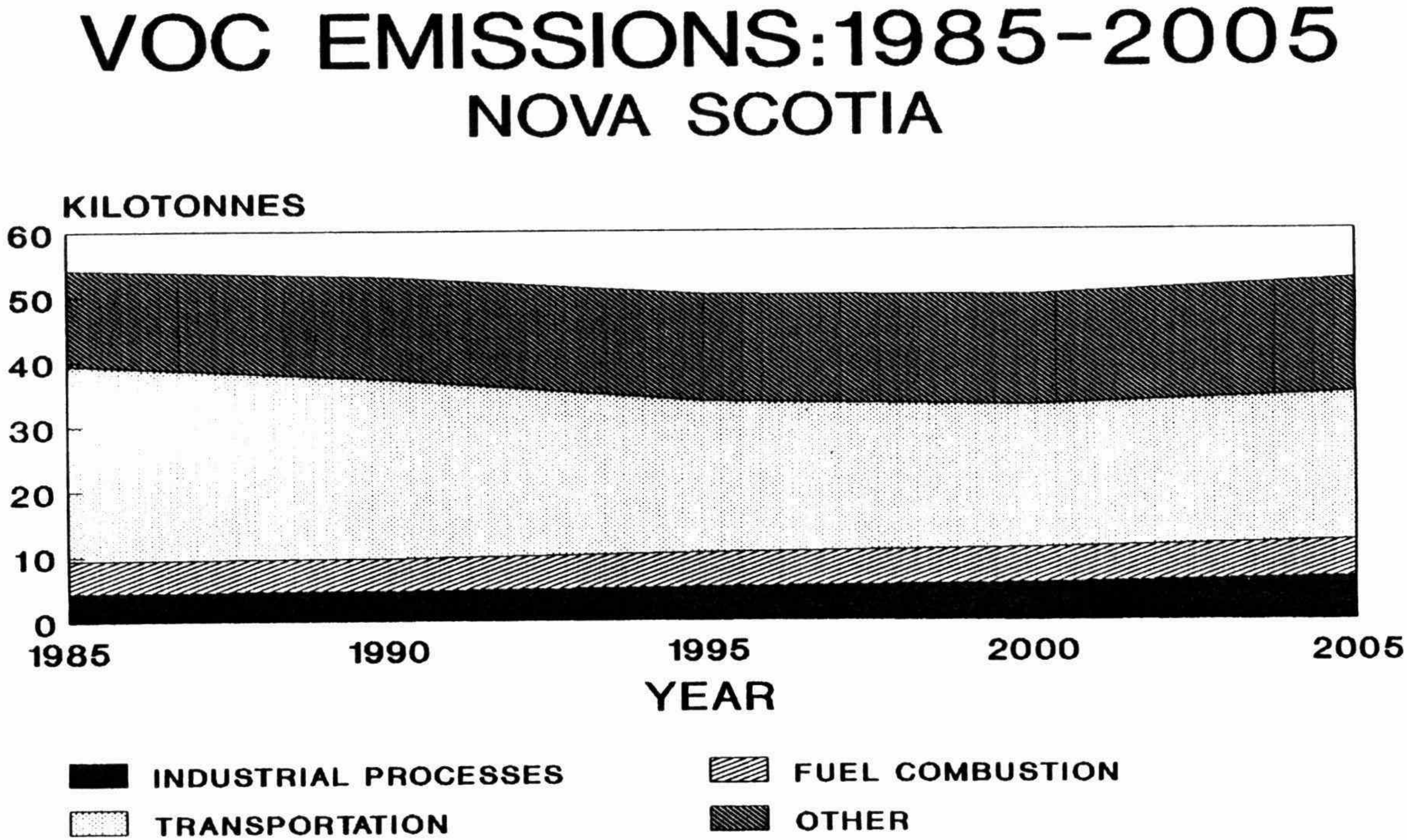

VOC EMISSIONS:1985-2005
NOVA SCOTIA
KILOTONNES
60
50
40
30
20
10
0
1985
1990
1995
2000
2005
YEAR
INDUSTRIAL PROCESSES
FUEL COMBUSTION
TRANSPORTATION
OTHER

FIGURE 3.2.5

VOC EMISSIONS:1985-2005
NEW BRUNSWICK

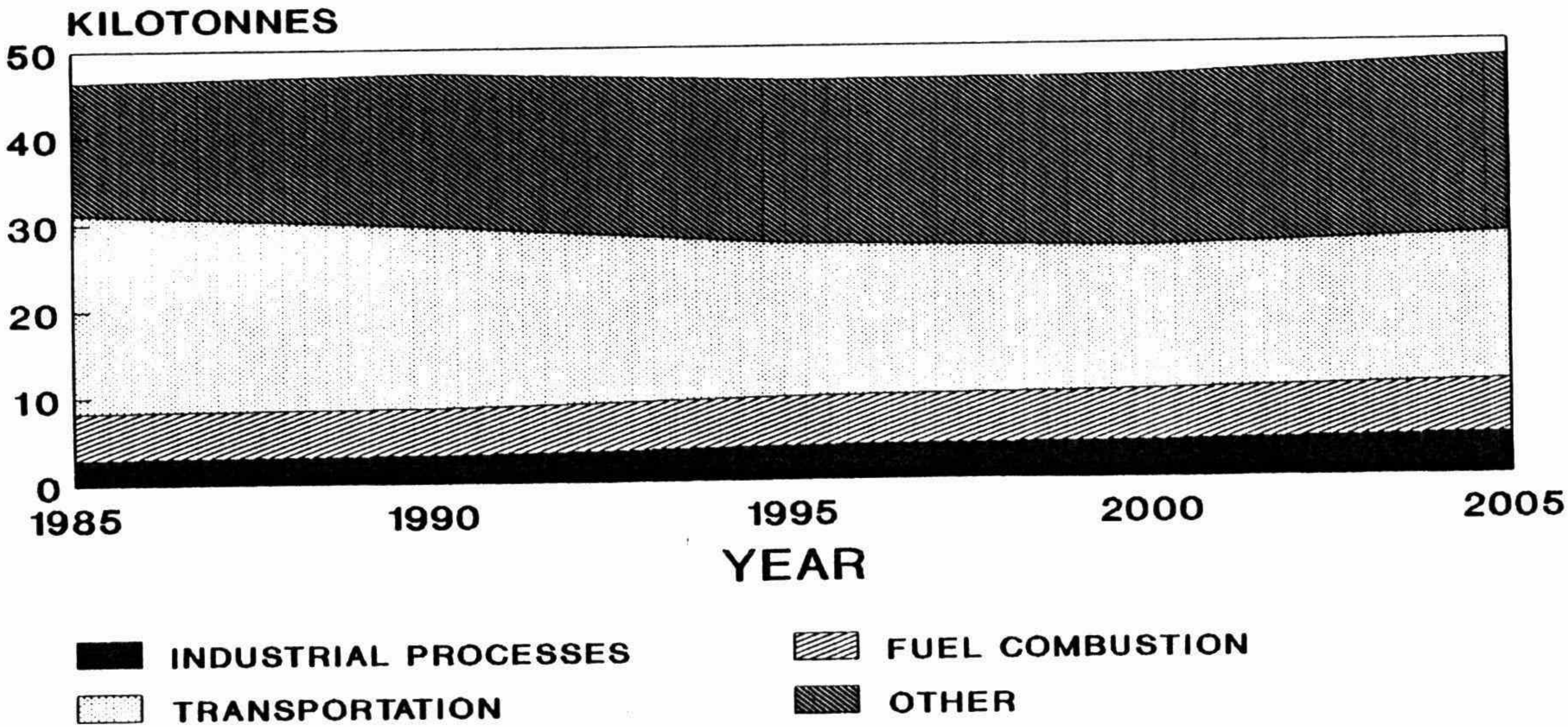


FIGURE 3.2.6

VOC EMISSIONS:1985-2005
QUEBEC

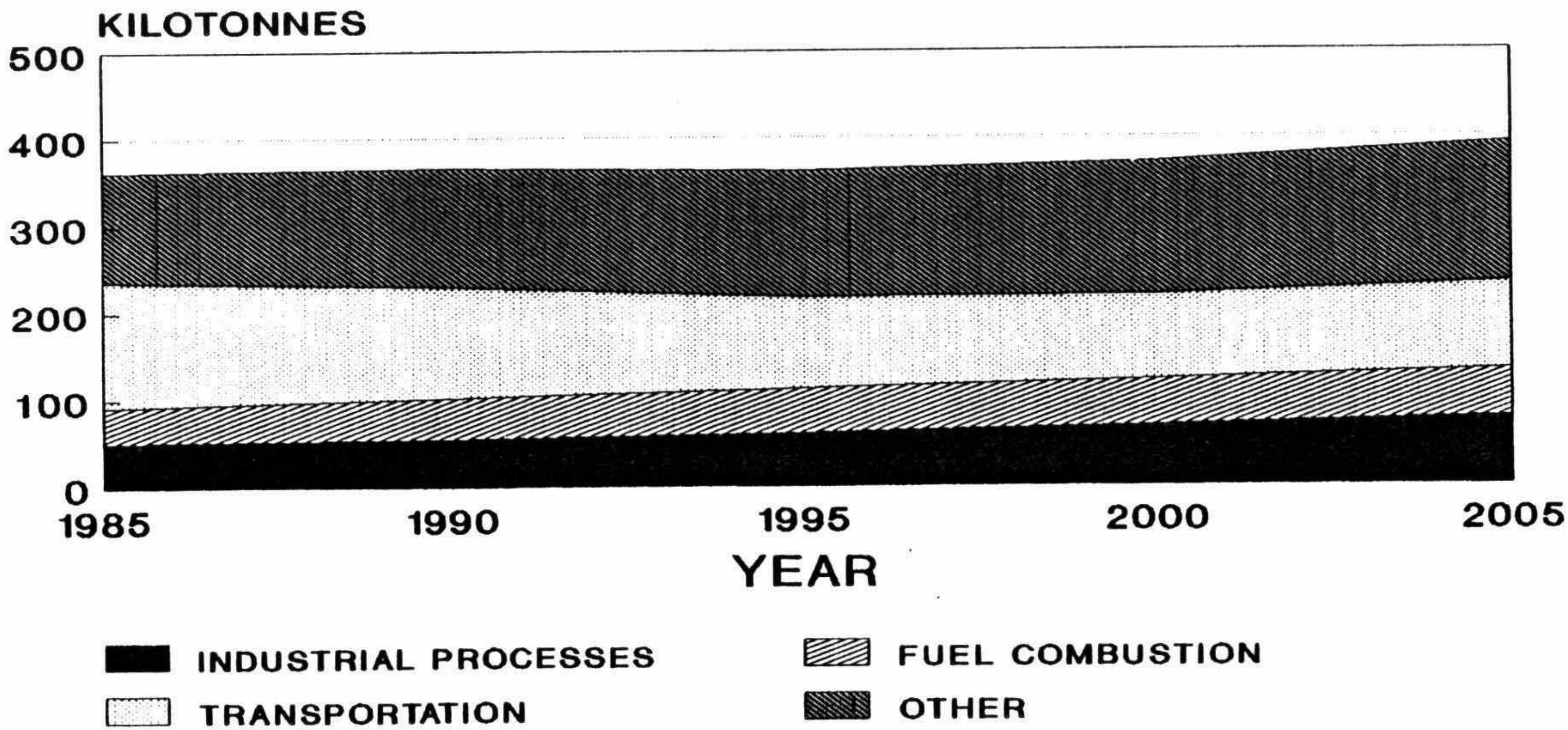


FIGURE 3.2.7

VOC EMISSIONS:1985-2005
ONTARIO

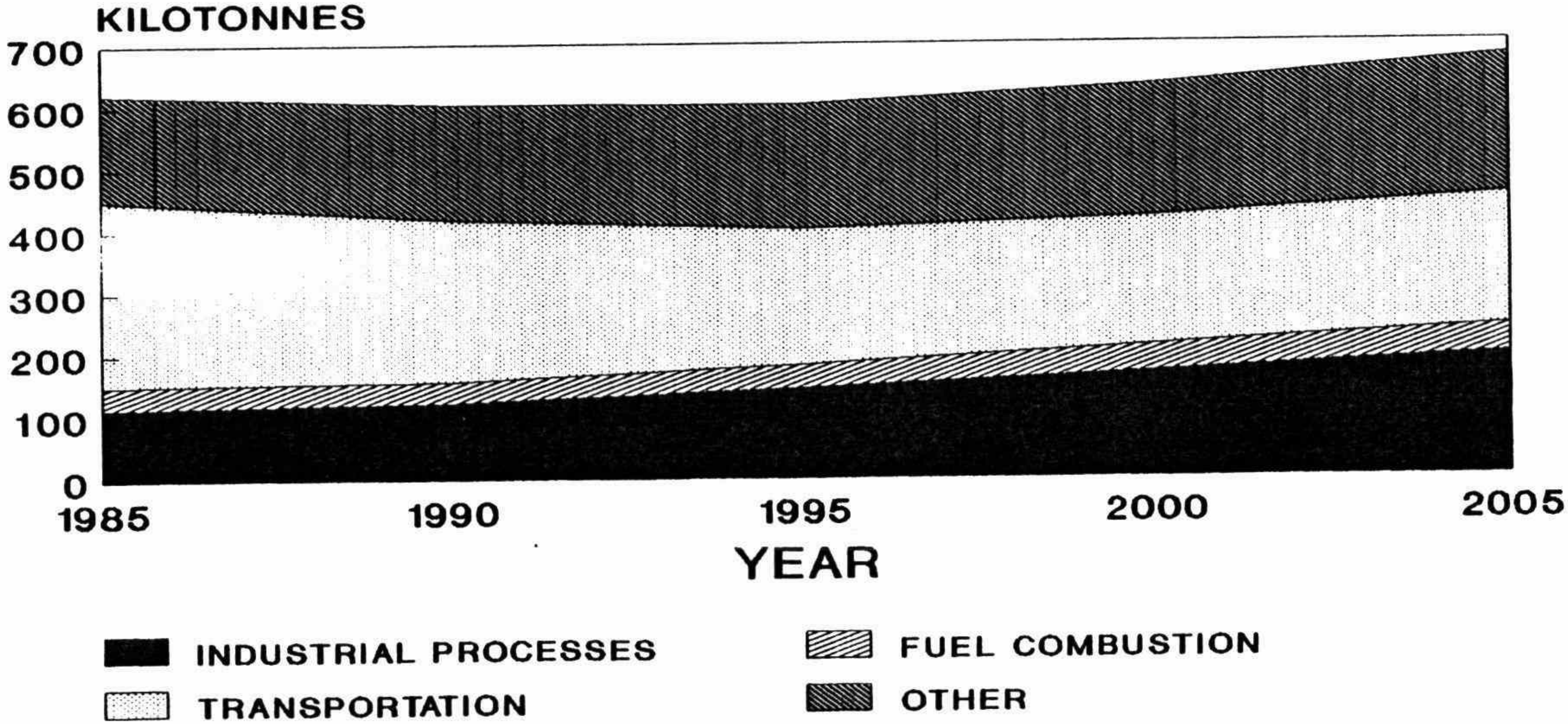
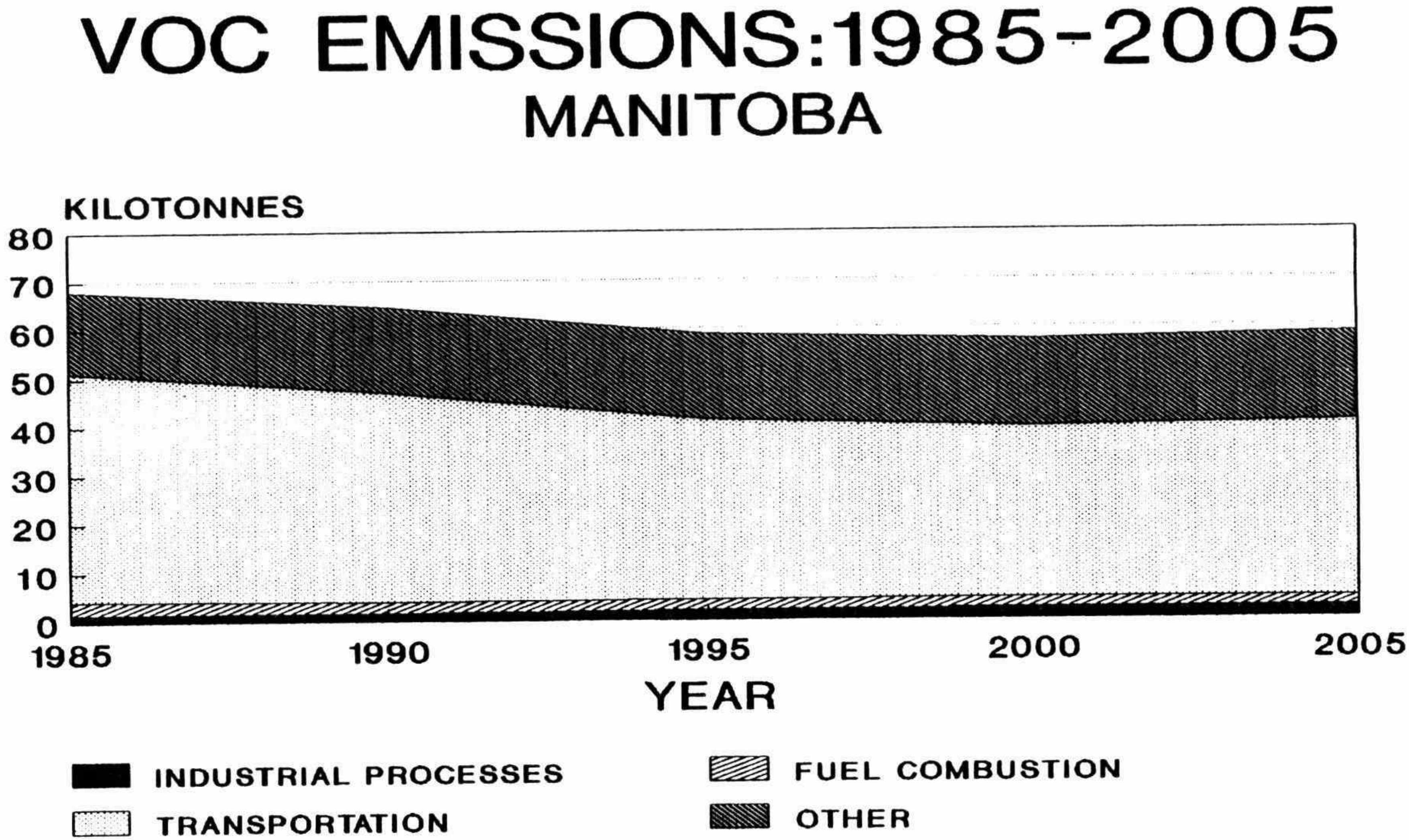


FIGURE 3.2.8



114

FIGURE 3.2.9

VOC EMISSIONS:1985-2005
SASKATCHEWAN

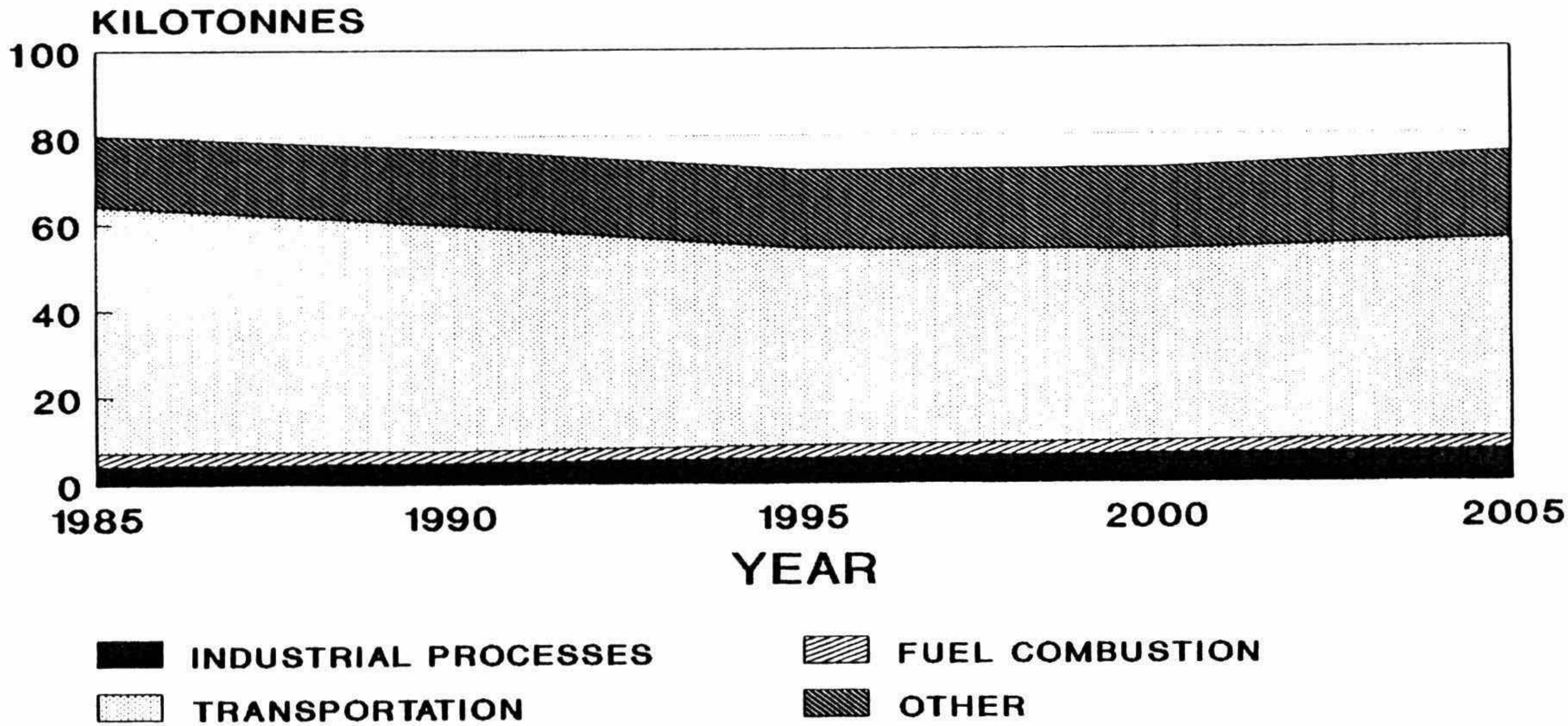


FIGURE 3.2.10

VOC EMISSIONS:1985-2005
ALBERTA

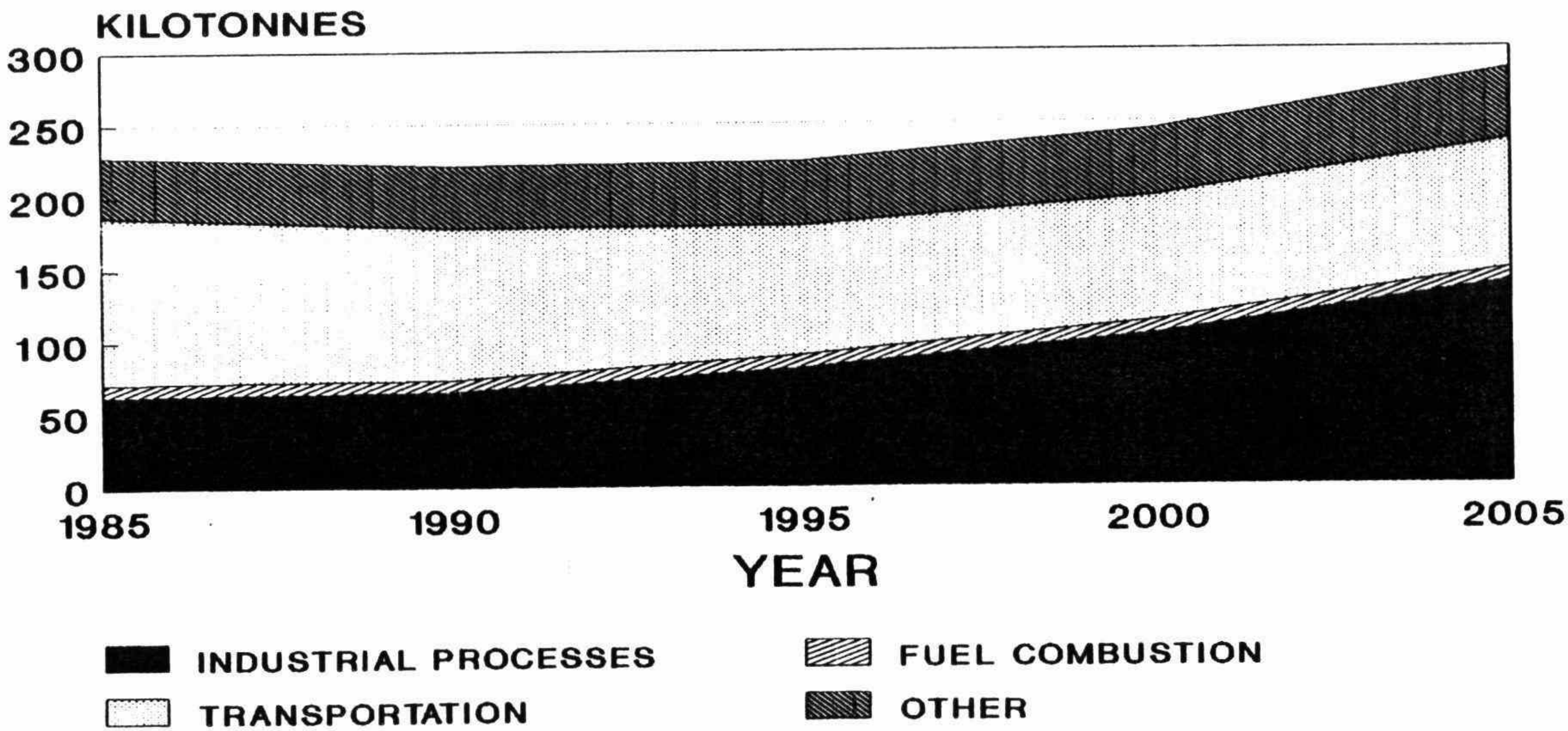


FIGURE 3.2.11

VOC EMISSIONS:1985-2005
BRITISH COLUMBIA

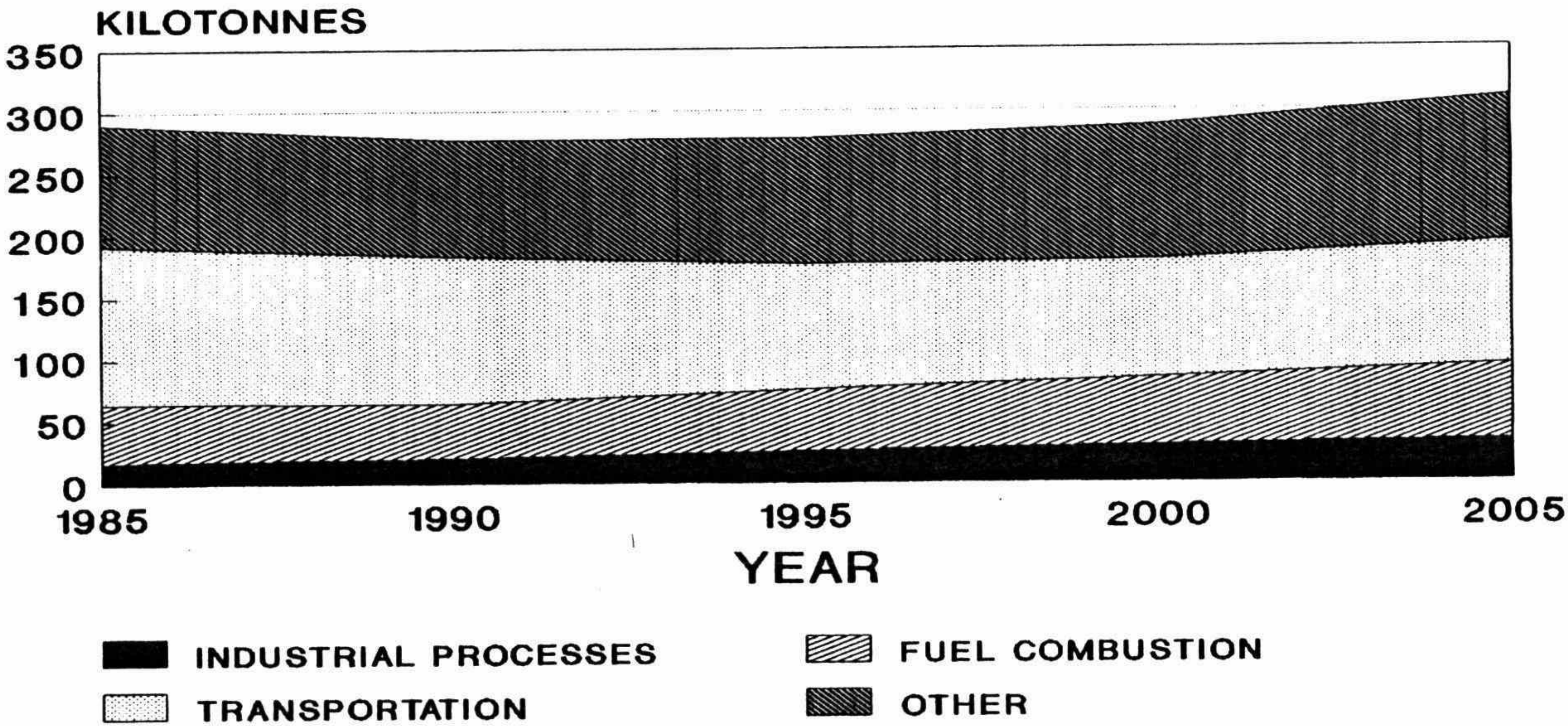
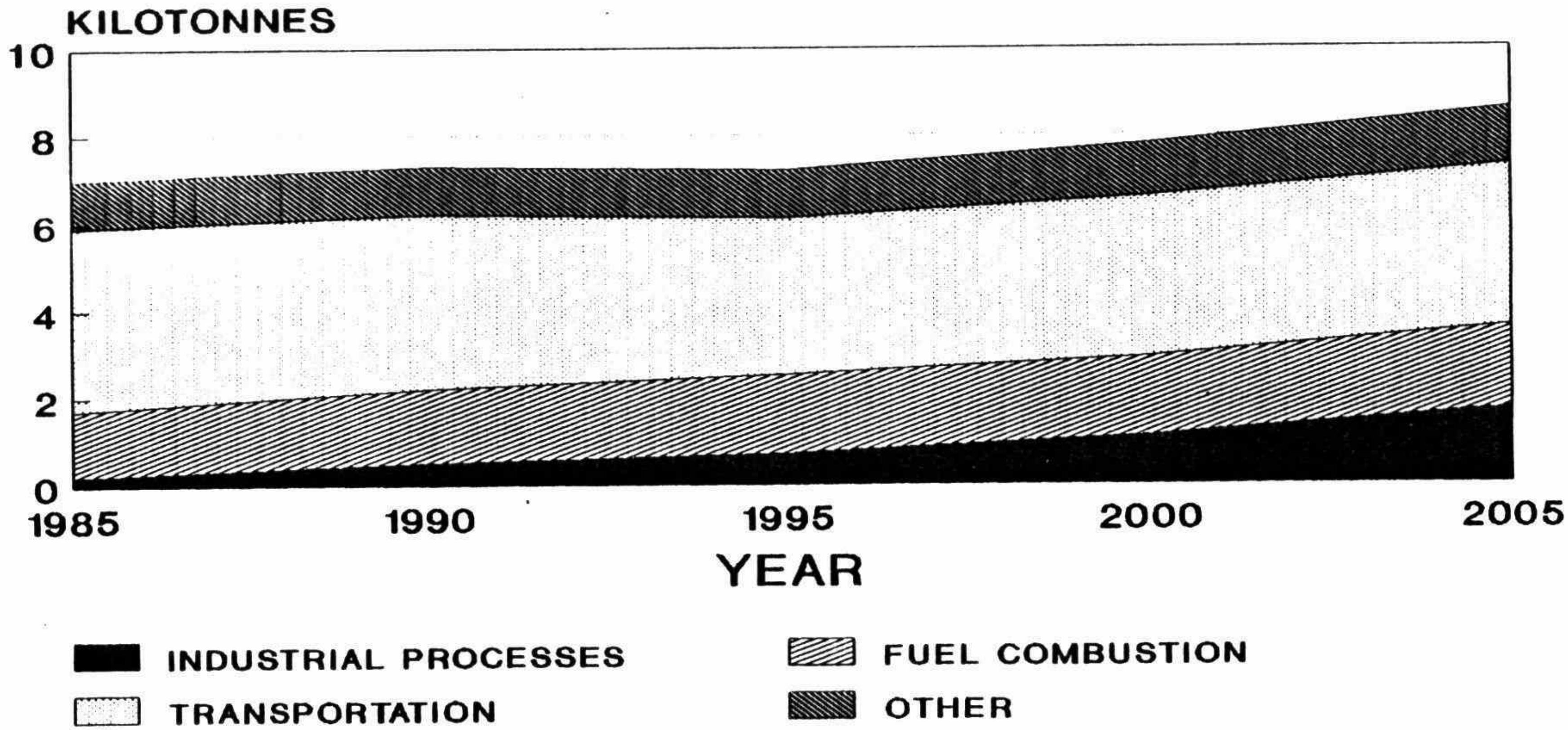


FIGURE 3.2.12

VOC EMISSIONS:1985-2005
YUKON/NWT



APPENDIX A

VOC Emission Projections

A. Base Year: 1985

Sources of Data (base year):

- motor vehicles - population - Statistics Canada
  - Transportation Systems Division (TSD), Env. Canada
  - emission factors - TSD
  - vehicle miles travelled - TSD
- other transportation - fuel consumption - Statistics Canada
  - emission factors - U.S. EPA (AP-42)
- fuel combustion - fuel consumption - Statistics Canada
  - emission factors - U.S. EPA
  - petroleum refineries:
    - emissions - provided by refineries and provinces
    - fuel consumption - supplied by refineries and provinces
    - emission factors - U.S. EPA
  - natural gas processing:
    - emissions calculated using emission factors from U.S. EPA and fuel consumption from provincial agencies
- power generation - emissions - fuel consumption from major plants (provincial utilities) used with U.S. EPA emission factors
  - additional emissions from small stations and gas turbines calculated from fuel consumption data and U.S. EPA emission factors
- industrial processes:
  - emissions data from 1985 inventory
  - petroleum refinery emission data based on PACE statistics + provincial information
  - petrochemical industry emissions obtained from internal Env. Canada report
  - data generated either through provincial agencies (point sources) or Statistics Canada production figures
- incineration/miscellaneous:
  - 1985 emissions data
  - emissions calculated by use of Statistics Canada data with emission factors

B. Forecast Years: 1986-2005

Sources of data:

- motor vehicles
  - emission factors - TSD
  - growth in car/truck stock by fuel type - National Energy Board (NEB) 1988 report
  - assumes no change in vehicle miles travelled

- other transportation
  - growth in energy consumption (e.g. 1987 vs. 1985 values) - NEB
  - province-specific statistics
  - assumes no change in emission factors or level of control technology available

- fuel combustion
  - industrial/commercial/residential - growth in energy consumption (for each fuel) - NEB
  - province-specific statistics
  - assumes no change in emission factors or level of control technology available

- petroleum refineries (fuel combustion)
  - growth in energy consumption (NEB)
  - no changes in emission factors or level of control technology

- natural gas processing (fuel combustion)
  - Informetrica GDP growth rates for "Petroleum & gas-resource extraction"
  - assumes no changes in emission factors or level of control technology

- power generation
  - emissions assumed to be constant throughout forecast period

- Industrial processes
  - Informetrica GDP growth rates used for following sectors:

    *bakeries - "Food and Beverage"
    *petrochemicals - "Chemicals"
    *metallurgical coke - "Petroleum & coal products - manufacturing"
    *aluminum production - "Primary metals"
    *sulphate pulping - "Pulp & paper"
    *tar sands - "Mining services"
    *crude oil production - "Petroleum and gas - resource extraction"

*coal industry - "Coal - resource extraction"
*carbon black - "Chemicals"
*plastics fabrication - "Chemicals"
*pulpboard manufacture - "Wood - manufacture"
*plywood/veneer - "Wood - manufacture"

- growth in energy consumption (NEB) for petroleum refineries
- data for growth rates are province-specific

- incineration/miscellaneous
  - population growth rates for growth in incineration practices
  - wigwam burners - Informetrica GDP growth rates - "Wood manufacturing"
  - slash burning - "Informetrica GDP growth rates - "Forestry"
  - gasoline marketing - NEB forecasts in motor gasoline consumption
  - structural fires - Informetrica growth for "households"
  - solvent use - Statistics Canada growth in "population"
  - surface coatings - Informetrica growth for "households"
  - dry cleaning - Statistics Canada growth in "population"

Note: All growth rates are for a "high growth" scenario as forecast by the NEB. Informetrica growth rates are based on their most recent tabulations from their economic model (TIM).

REPORT NO. 3.3

VOC CONTROL TECHNOLOGIES

Prepared for:

Federal-Provincial Advisory Committee
on Air Quality

Conservation and Protection
Environment Canada

July 1989

3.3 VOC CONTROL TECHNOLOGIES

3.3.1 Introduction

This section identifies the options available to control VOC emissions from stationary and mobile sources. Gross estimates of the emission reductions and their associated costs are also provided for discussion. These reduction potentials and costs estimates wastes all assume a consistent application of the proposed technologies across the country. The data have been extracted from readily available sources identified in Appendix A.

Projects underway with respect to emission inventories, penetration of control technologies, other control options available and economic impacts of propose control options may modify the preliminary information contained in this section.

Potential emission reductions and cost effectiveness of control options are also subject to changes as emission forecasts are modified.

Those technologies presented in the tables should not be interpreted as preferred technologies but are presented to indicate the range of VOC reduction possible and generally include a high efficiency (and sometimes high cost) removal technology for each sector. In a more detailed sectoral or regional analysis, other possible technologies should also be examined in selecting a control level or plan.

The information presented is intended to provide preliminary national, regional and sectoral pictures on VOC control opportunities and provide a common basis for all stakeholders to begin discussion on a Canadian VOC control strategy. The national picture will be re-examined and re-presented periodically during the course of discussions as preferred control options are identified.

3.3.2 VOC Control Options

Table 3.3.1 summarizes the VOC control options that have been selected, the expected reductions in year 2005 and their associated costs.

The reader will notice that there are three columns reflecting different reduction efficiencies. The "Current Control" column shows an estimate of the efficiency of the option at the present time.: This percentage is a reflection of the level of penetration of the control option for a given source. The "From No Control" column lists the theoretical reduction efficiency of the proposed option for a given uncontrolled source.

The following column (Additional Red. in 2005) gives an estimate of additional reductions that are possible for the source category in the year 2005.

Table 3.3.2 is a breakdown of potential emission reductions by province by type of source.

3.3.3 Technology Description

The control options identified in Table 3.3.1 are described below.

A. **MOBILE SOURCES**

1. Light Duty Gasoline Vehicles (LDGVs)

1.1 LDGV California Standards

Reducing tailpipe hydrocarbons emission standards for LDGVs would require higher precious metal loading of three-way catalysts, better air-fuel mixture control, and for a few vehicles, possibly the use of a by-pass catalyst. Better air-fuel ratio control can be achieved through changes in

engine computer software and through greater use of fuel injection. Manufacturers would probably tend to use more port and sequential fuel injection than would be the case if standards stayed at the present level. California also has stricter standards for NOx emissions.

- NOx reduction potential 60%
- HC reduction potential 95%
- Status: adopted in California
- Cost: $90/vehicle (total cost of $180 for both HC and NOx reductions

1.2 LDGV Inspection and Maintenance (I/M)

The emissions control equipment originally installed on new vehicles is designed to function within specification for the "useful life" of the vehicle which is presently defined as 5 years or 50,000 miles. For the latest model vehicles in particular, if a vehicle is maintained in accord with the manufacturer's recommended schedule and not misfuelled, this equipment should operate efficiently for considerably longer than 50,000 miles, thus maintaining NOx emissions, and those of the other regulated pollutants, CO, THC, and particulates, at low levels.

However, clinics and surveys in both Canada and the U.S.A. have shown that between 20 and 50% of the light duty vehicles on the roads may have emissions in excess of the regulated standards. These higher emission result not only from the rigors of on-road driving, but from the lack of sufficient maintenance and from tampering with vehicle Emission control systems. Each province should adopt regulations for in-use motor vehicles which prohibit tampering and, thereby encourage proper maintenance. Such regulations should be accompanied by some form of enforcement program.

Depending upon the severity of the air quality problem, the enforcement programs should include some or all of the following: a pro-controls/anti-tampering publicity campaign, a mechanic/dealer education program, a dealer/mechanic enforcement program and an inspection and maintenance program (I/M). Regular compulsory I/M inspections are now required in over 50 major urban areas in the U.S.A.

An I/M program should include, as a minimum, an inspection on vehicle re-sale, but could require a compulsory, annual vehicle inspection.

California is actively investigating requirements for the standardization of vehicle computer systems (both hardware and software components) and the application of new computerized diagnostics in connection with vehicle inspections and repair. The implementation of these sophisticated techniques could improve repair efficiency, as well as reduce repair and inspection time and costs. The result would be less inconvenience for the vehicle owner and a greater likelihood of correct and efficient diagnosis and repair. A reduction in CO and NOx emissions would invariably accompany such innovations.

- NOx reduction potential 5%*
- VOC reduction potential 25%
- SO_2 reduction potential 0
- CO_2 reduction potential 0 to 2.5% (as a result of fuel savings)
- CO reduction potential 30%
- Status: Program requirements, procedures available
- Cost: $15/vehicle/year.

* Reduction from present fleet. This reduction is expected to increase if tighter NOx standards are adopted. As emission control systems become more efficient the benefits from better maintenance and reduced tampering increase.

1.3 Gasoline Votality Reduction

Reducing gasoline vapour pressure by 17 KPa from May to September would reduce overall hydrocarbon emissions by 10 to 13% from light duty vehicles for this period. This represents a 5 to 6.5% annual reduction. This estimate is low because it does not include the effect of volatility reduction on running losses and evaporative emissions from off-road vehicles which are uncontrolled. Evaporative emissions which occur while the vehicle is running, aptly named running losses, could not be modelled at the time of publication. These emissions can be larger than other evaporative emissions from motor vehicles. There are no reliable estimates of the evaporative losses from vehicles used off road.

- VOC reduction potential 10-13% of emissions from LDV, LDGT, HDGT

- Status: In effect in California and some New England States. Ontario will reduce volatility by 7 KPa during the summer of 1989.

1.4 Better Evaporative Emissions Control

General

All new gasoline vehicles now have control systems for evaporative emissions. In these systems, the fuel tank and carburator are vented to a canister filled with activated charcoal. Hydrocarbons emitted from the fuel system are absorbed onto the charcoal. When the engine is started, the vaccum in the intake system is used to draw fresh air through the canister to purge it of hydrocarbons. The hydrocarbons are then burned in the engine.

Present evaporative systems do not capture all the hydrocarbons vapour escaping from the fuel system. Once the canister is

full, the excess hydrocarbons pass through and are released to the atmosphere.

There are two possible ways of reducing evaporative emissions. One is to reduce fuel volatility and the other is to require better vapour control systems on the vehicles. Combining a modest amount of volatility control and a better evaporative emissions control system is also possible.

The EPA had proposed a regulation that would have required onboard control of refuelling emissions. The calculated emissions reductions are based on the assumption that better evaporative emission control systems could control evaporative emissions from gasoline at 79 KPa to the same extent present systems do with 62 KPa gasoline. RVP reduction would also reduce emissions from tampered or defective vehicles. This represents the maximum improvement attainable from better evaporative systems by the year 2005 (running losses are not considered).

Since then, US EPA has confirmed that it will be reducing gasoline vapour pressure to 62 KPa and the president of the United States has announced that onboard control of refuelling emissions will not be required. Reducing fuel volatility to 62 KPa will not eliminate running losses or evaporative emissions. It is expected that the requirements for evaporative systems will be changed so that vehicles will have higher purge rates and larger canisters to ensure almost complete control of evaporative losses with 62 KPa gasoline. There is no information yet available on cost and performance of such upgraded systems.

In the absence of a requirement for onboard systems in the U.S., the cost of onboard control of refuelling emissions in Canada becomes much higher than previously estimated.

Therefore, onboard controls is not considered because a more cost-effective option exists to control refuelling emissions.

1.5 Other Control Options Considered

Heavy Duty Gasoline Vehicles (HDGVs) Emissions Standards

HDGV up to 14,000 lbs gross vehicle weight rating (GVWR) usually have an oxidation catalyst to meet the more stringent hydrocarbon and carbon monoxide limits set for these trucks. Hydrocarbon and carbon monoxide standards for heavy duty trucks above 14,000 lbs GVWR are more lax because catalyst cannot withstand the high exhaust temperatures found in these larger trucks.

There are at present no firm proposals for further control of tailpipe hydrocarbon emissions from heavy duty vehicles.

Diesel Engines Emission Control

Diesel Engines emit relatively low amounts of hydrocarbons, usually much below regulated levels. No direct control of hydrocarbon emissions are being contemplated but regulations limiting particulate emissions will indirectly reduce hydrocarbon emissions.

B. STATIONARY SOURCES

1. GASOLINE MARKETING

1.1 Marketing Terminals - Installation of Internal Floating Roofs

Internal floating roofs could be made mandatory for marketing terminal tanks. It is estimated that 2/3 of these tanks already have floating roofs. Internal floating roofs can reduce the VOC

emissions from fixed roof tanks by 96%. An alternative to installing floating roofs to smaller tanks is to route the tank losses to a vapour recovery system.

1.2 Vapour Recovery at Marketing Terminals

This control option consists in condensing adsorbing or incinerating the vapours emitted during fuel transfer operations. When carbon adsoption is used, the vapours are periodically desorbed from the carbon column and recovered. It is estimated that 79 to 90% of the vapour can be recovered by this technology.

1.3 Vapour Balancing at Bulk Plants

The vapour balancing system consists in a closed system between the tank trucks or rail cars delivering gasoline and the storage tanks.

The net effect of the system is to transfer vapour from the storage tanks to the delivery trucks as they unload their content and to transfer vapour from the trucks being loaded to the storage tanks.

This control technique requires that marketing terminals and refineries to some extent be equipped with vapour recovery systems. US EPA has estimated the theoretical efficiency of this technique at 95%. The in-use efficiency would however be about 84%.

1.4 Vapour Balancing, Service Station Delivery

Emissions from underground tank filling operations at service stations can be reduced by the use of a vapor balance system (Stage 1 Control). In the service station balance system, vapors which would normally be vented to the atmosphere when the underground tank is being filled up are routed back to the delivery truck, through a vapor collection system. The truck transfers the vapors

to the terminal or bulk plant for ultimate treatment by the vapour processors at the terminal.

A control efficiency of 95% is reported.

1.5 Vapour Balancing - Vehicle Refuelling

Emissions from vehicle refuelling operations can be reduced by the use of a vapour balance system (Stage 2 control). Car tank vapours which would normally be vented to the atmosphere are routed back to the service station underground storage tank through a vapour collection system installed on the dispensing equipment. As indicated in Stage 1 control description above, the vapours are then transferred (through delivery trucks) to the terminal, bulk plant or refinery for processing.

The theoretical efficiency of such a system (95%) is affected by the reliability of components, routine maintenance and public acceptance of the system. Tampering is also an important factor and an inspection program would be necessary. In use efficiency varies between 48 and 92% in the literature.

1.6 Gasoline Volatility Reduction

This control option would consist in having the refineries reduce the volatility of gasoline from May to September. A reduction of volatility (RVP) of 17 kpascals (from 11.5 to 9 PSI) would result in a 8% to 10% reduction of the annual emissions of VOC from the gasoline marketing and distribution sector. The potential impact of this reduction on ozone formation is greater than a reduction of a similar magnitude spreaded over the year since it all occurs during summer time.

2. PETROLEUM REFINERIES

2.1 Quarterly Inspection and Maintenance Program

Fugitive emissions from refineries may represent 50% of their total emissions. Controlling these emissions would imply a program to be put in place to prevent or minimize leaks from valves, flanges, compressors and pumps. Certain types of equipments that allow less emissions may also be recommended. Quartely inspection and maintenance of the most important components could reduce uncontrolled emissions by 69 to 80%.

2.2 Floating Covers on Waste Water Separators

Emissions from this source may represent 6 to 12% of total emissions. To control these emissions, oil/water separators at waste water treatment plants could be covered by a floating roof. This could reduce the emissions by 90 to 95%.

2.3 Secondary Seals on External Floating Roofs

Secondary seals could be added to external floating roof storage tanks equiped with primary seals only. These later seals are 15 times less efficient.
The difference in control efficiency between tanks in gasoline service and tanks in crude service (95% versus 83 to 90%) is that VOC emissions from gasoline tanks are higher than from crude tanks. This also results in a faster cost recovery of the equipment installed. Only a small number of tanks are equiped with external floating roofs in Canada so reductions would be small.

2.4 Internal Floating Roof on Tanks in Volatile Hydrocarbon Service

Internal floating roofs could made mandatory for tanks that store high volatility liquids. It is estimated that only 10% of these

tanks are still not equipped with some type of floating roof. Control efficiency of internal floating roofs varies between 96 and 98%.

2.5 Vapour Recovery for Gasoline loading at Refineries

Recovery of gasoline vapours during loading into truck and barges or tankers is another option to consider. Although emissions during loading of gasoline may only represent 7% of total refinery emissions. This option could be attractive if gasoline vapour processing at refineries is made necessary because of vapour control in the marketing network.

3. PETROCHEMICAL INDUSTRY

There is at present, very little information on controls already in place in the petrochemical industry so that achievable reductions cannot be accurately estimated at this time. The sources of emissions are very similar to the petroleum refining sector: process emissions, fugitive emissions (equipment leak) and emissions from storage and handling of the feedstocks and products. Control technologies would also be similar: capture and destruction or recovery of process emissions, improved maintenance programs and adoption of best management practices to reduce fugitive emissions, reduction of storage losses by the installation of floating roofs on tanks storing volatile organics and recovery of loading emissions when necessary. It is estimated that a theoretical reduction of up to 90% from uncontrolled levels is possible. It was assumed that 45% of the current emission projections could be controlled by the year 2005. Cost per ton of VOC removed ranges from a low of $25/tonnes to $6,200/tonne depending on the control technology and plant size.

4. SURFACE COATING

Technologies are available to reduce VOC emissions from surface coating and printing by 70 to 90 percent from uncontrolled levels.

There is very little information on level of control installed as a result of regulations or because of ongoing process improvements so that it is not possible to adequately estimate the amount of reduction achievable form this sector. Emissions can be divided into two categories: Those resulting from commercial and industrial applications and those released to consumer product use. Control technology for industrial and commercial emissions would involve the capture and destruction or recovery of the emissions. Control of emission at the consumer level implies a reformulation of coatings to reduce their organic solvent content. A figure of 40% was used to estimate the potential reduction of emissions. Cost controls vary from a net profit to $10,000 per ton of VOC depending on the size of operations and degree and type of control.

5. DRY CLEANING

Theoretically, up to 99% of VOC emissions can be recovered from dry cleaning operations by the use of carbon adsorption or incineration. The cost of controls varies with the size of the source. Large sources could be controlled at a net profit while controlling small sources could cost up to $14,000/tonne of VOC recovered. Incorporating best management practices techniques and good preventive maintenance, frequent inspections and monitoring and other loss control techniques would have a significant impact for operations which are old and do not have state-of-the-art control technologies. Substitution to lower volatility cleaning fluids could also be contemplated. Because of the number of sources, their type and the high costs to control some of them, a conservative 35% reduction of emissions in year 2005 has been used in this report.

6. SOLVENT USE

This category covers diversified sources such as consumer products, industrial solvent use and metal degreasing. Solvent recovery is possible for some applications such as major metal degreasing

operations and industrial uses. Recovery efficiencies reported range from 54 to 83 percent depending on the size of the source. Cost of control ranges from a net profit to a cost of $170/tonne of VOCS. Some of the larger sources may already be controlled to some extent because of cost savings. Other sources such as home use of products containing organic solvents, cannot be controlled except by product substitution or reformulation. Small industrial use of solvents is difficult and expensive to control. The achievable reductions for each of the subcategories cannot be estimated at this time because of the lack of information.

A conservative 33% emission reduction in year 2005 has been used in this report.

7. FUEL COMBUSTION

Fuel combustion produces relatively little VOC except for residential wood burning which is a large source VOC emissions. The only technology known to reduce VOC emissions from residential wood stoves is the oxidation catalyst. Theoretical reduction in VOC emissions from this technology is not known. Few stoves are ever replaced so that any reductions in emissions by the use of better combustion technology would take place over a long period of time. The only effective short and medium term control is to reduce residential fuel wood use.

Residential wood burning occurs outside of the ozone season May to September). While reductions from this sector could help reduce overall VOC emissions, any reduction from this source would not improve air quality during the ozone season. Residential fuel combustion is a large source of PAHs and particulates so controls on this source may be warranted but not as part of an ozone control strategy.

TABLE 3.3.1

SUMMARY - SELECTED VOC CONTROL OPTIONS, EMISSION REDUCTION POTENTIAL AND COSTS

CONTROL/TECHNOLOGY	APPLICATION ASSUMPTION	CURRENT CONTROL (%)	VOC REDUCTION POTENTIAL FROM NO. CONTROL (%)	ADDITIONAL RED. IN 2005 (%)	ADDITIONAL RED. IN 2005 KT/YR	COST (1987$) PER UNIT	ANNUAL IN 2005 ($ X 10^6/YR)
A. Mobile Sources							
Light Duty Gasoline Vehicle (LDGV)							
(1) LDGV - California Stds (1)	Effective 1997	90	95	15	56.0	$90/veh. 1600/tonne	90
(2) LDGV Inspection/Maintenance	Effective by 2005	0	40	25	96.8	$15/veh/yr + maintenance	128+
(3) Gasoline Volatility Reduction (2)(3)(5)	Effective by 1999	0	10-13	5-6.5	25.2	2200/tonne	55
(4) Better Evap. Systems (4)(2)(12)	Effective 1994	80	90	5-7	28.3	$5-10/veh	
B. Stationary Sources							
Gasoline Marketing							
(5A) Internal/floating roofs for storage at marketing terminals	Effective by 2005	63	96	4	5.5	$(-349)-(-140)/	(1.9)-(0.8)
(5B) Vapour Recovery at Marketing Terminals	Effective by 1999	0	79-90	11-12.5	14-16	($-301)-$575	(4.5)-8.6
(5C) Vapour Balancing Bulk Plants	Effective by 1999	0	84	8	10.6	$190/tonne	2.0
(5D) Vapour Balancing Service	Effective by 1999	0	95	25	31.9	$17-310/tonne	0.5-9.9
(6) Vapour Balancing, Vehicle Refuelling (Stage 2) (6)	Effective by 1999	0	48-92	19-36	24-45	$1250-4050/tonne	43.1-139.7

TABLE 3.3.1

SUMMARY - SELECTED VOC CONTROL OPTIONS, EMISSION REDUCTION POTENTIAL AND COSTS

CONTROL/TECHNOLOGY	APPLICATION ASSUMPTION	CURRENT CONTROL (%)	VOC REDUCTION POTENTIAL FROM NO. CONTROL (%)	ADDITIONAL RED. IN 2005 (%)	KT/YR	COST (1987$) PER UNIT	ANNUAL IN 2005 ($ X 10^6/YR)
(7) Gasoline volatility Reduction (17 kpascals) Storage, Handling, S.S. Delivery and Refuelling Losses (3)(5)(7)(8)	Effective by 1999	0	8-10	10	10.2-12.8	$2200/tonne	22.4-28.2
Petroleum Refining							
(8A) Quarterly Inspection and Maintenance Program for Fugitive Emissions (9),(10)	Effective by 1999	35-40	69-80	20-23	10-11.5	$(-239)-251/tonne	(2.6)-2.7
(8B) Floating Covers on Wastewater Separators (11)	Effective by 1999	0	90-95	5-11	2-5	$(-199)-625/tonne	(0.7)-2.2
(8C) Secondary Seals on External Floating Roofs for Storage of:	Effective by 1999						
- Gasoline		?	95	7	3.5	$0-1485/tonne	0-5.2
- Crude Oil		?	83-90	1	0.5	$7777-15031/tonne	3.9-7.5
(8D) Internal Floating Roof for Storage of:	Effective by 2005						
- Gasoline		85	96	18	9	$(-349)-(-196)/ tonne	(3.1)-(1.8)
- Crude Oil		91	98	5	2.5	$(-215)-40/tonne	(0.5)-0.1
- Other volatile products		74	98	6	3	$(-215)-40/tonne	(0.6)-0.1
(8E) Gasoline Loading at Refineries: Vapour Recovery (11)	Effective by 1999	0	89	6	3	$1990/tonne	6.
(9) Petrochemicals	Effective by 2005	?	90	45	97.1	$25-6,200/tonne	2.4-602
(10) Surface Coating	Effective by 2005	0	70-90	40	66.7	$0-10,000/tonne	0-667
(11) Dry Cleaning	Effective by 2005	?	70	35	17.4	$0-4,000/tonne	0-69.6
(12) Solvent Use	Effective by 2005	?	54-83	33	38.9	$0-170/tonne	0-7
Total*							340-1830

*Total is the sum of items 1, 2, 3, 5, 6, 8, 9, 10, 11, 12

NOTES TABLE 1

1. Theoretical and potential reduction are expected to change when calculated using MOBILE4.

2. Both control options (volatility reduction and better evaporative systems) can be used to control the same emissions. Reductions are therefore not additive.

3. Cost per tonne of VOC removed may be significantly lower when energy savings to the consumer are taken into account. Cost estimates vary by an order of magnitude in the literature.

4. Savings are expected because of value of fuel recovered. These saving are largest if better evaporative systems are used rather than volatility reduction.

5. These reductions would occur during the period of May to September. They will, therefore, have a greater impact (approximately twice) on ozone formation than reductions from other measures which reduce emissions over the whole year.

6. Theoretical efficiency is about 95% but it is expected that reliability of the equipment, frequency of maintenance, public acceptance and tampering would greatly reduce the efficiency. An in-use efficiency of 48-92% is estimated to be achievable.

7. A 24% reduction over a 5 months period is assumed to be equivalent to a 10% reduction of the annual emissions.

8. These emission reductions cannot be added to other reductions because they are basically also achieved by the other control systems/options.

9. Quantity of fugitive emissions need to be better estimated.

10. Detailled information has to be obtained on I&M programs proposed in the U S and in other countries.

11. These emissions have not been properly estimated yet. Potential reduction based on reference data.

12. Current Control efficiency shown is for vehicles under standard testing conditions. Efficiency varies with ambient conditions, driving cycles and fuel volatility.

TABLE 3.3.2
VOC CONTROL TECHNOLOGIES - REDUCTION POTENTIAL BY PROVINCE (KT/YR - YEAR 2005)

	MOBILE SOURCES						STATIONARY SOURCES						
	(1) NEW LDGV	(2) LDGV MAINT.	(3) GAS VOLAT.	(4) VEH. EVAPOR.	(5) GAS DIST.	(6) VEH. REFUEL.	(7) GAS VOLAT.	(8) REFINERIES	(9) PETRO CHEMICALS	(10) SURFACE COATING	(11) DRY CLEANING	(12) SOLVENT USE	TOTAL CANADA
B.C.	8.2	14.9	3.8	4.3	6.2	3.4	1.5	4.8	1.1	6.9	2.0	4.6	55.9
Alta.	6.8	11.9	3.1	3.5	6.2	3.4	1.4	4.4	47.0	3.5	1.6	3.6	91.5
Sask.	2.7	5.3	1.4	1.5	2.4	1.3	0.4	1.3	-	1.8	0.7	1.7	18.6
Man.	2.8	5.0	1.3	1.5	2.7	1.5	0.4	-	-	2.0	0.7	1.6	17.6
Ont.	19.4	32.7	8.6	9.6	27.6	15.0	4.4	14.2	32.4	31.8	6.4	14.2	202.3
Que.	11.3	18.4	4.9	5.5	12.7	7.1	2.5	5.9	16.6	16.9	4.3	9.5	107.6
N.B.	1.5	2.8	0.7	0.8	1.7	0.9	0.3	1.1	-	1.3	0.5	1.1	11.6
N.S.	2.0	3.4	0.9	1.0	2.0	1.1	0.3	2.9	-	1.2	0.6	1.3	15.4
Nfld.	0.9	1.6	0.4	0.4	1.0	0.5	0.2	0.9	-	1.0	0.5	1.0	7.8
P.E.I.	0.3	0.5	0.1	0.1	0.3	0.2	0.1	-	-	0.3	0.1	0.2	2.0
Y/NWT	0.1	0.3	0.0	0.2	0.1	0.1	-	0.3	-	-	-	0.1	1.1
	56.0	96.8	25.2	28.3	63.0	34.5	11.5	35.8	97.1	66.7	17.4	38.9	531.4

(1) Reducing gasoline volatility will reduce emissions from both mobile sources and the gasoline marketing system. Reductions are shown separately in column 3 and 7.

(2) The total reduction by Province is the sum of columns 1, 2, 3, 5, 6, 8, 9, 10, 11, 12. Emissions reductions in columns 4 and 7 have not been added because they are alternate means of achieving the emission reductions shown in other columns.

(3) Potential emission reduction from the gasoline marketing network are divided in three columns in this table. Column (5) includes reduction associated with bulk and marketing terminals and with service station delivery (Stage 1). Column (6) includes reduction associated to vehicle refuelling. Finally column (7) show the potential reduction from gasoline volatility reduction over the whole marketing network.

APPENDIX A

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